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3 FUZZY LOGIC BASED SYSTEM AND METHOD FOR INFORMATION

4 PROCESSING WITH UNCERTAIN INPUT DATA

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6 STATEMENT OF THE GOVERNMENT INTEREST

7 The invention described herein may be manufactured and
8 used by or for the Government of the United States of
9 America for Governmental purposes without the payment of any
10 royalties thereon or therefore.

11

12 BACKGROUND OF THE INVENTION

13 (1) Field of the Invention

14 The present invention relates generally to data
15 integration and decision support systems based on fuzzy
16 logic and, more specifically, to a fuzzy logic based system
17 and method for information processing that is capable of
18 handling uncertainty in the input data.

19 (2) Description of the Prior Art

20 Combat system information processing entails the
21 integration of data from diverse sources for tactical
22 picture generation and maintenance, situation assessment and
23 planning, and allocation/control of resources. Current
24 methods for data integration and decision support in
25 submarine combat systems do not adequately account for
26 uncertainty in the input data in an automated fashion.
27 Instead they rely heavily on operator manipulation and human

1 interpretation. On the other hand, in recent years the
2 amount and flow rate of input data for integration has been
3 rapidly increasing. It is anticipated that advances in
4 sensor technology will continue to offer more possibilities
5 in gathering both acoustic and non-acoustic data from
6 organic as well as off-board sources, environmental and
7 kinematic monitors, and intelligence reports. The combat
8 system of the future therefore requires the ability to
9 automatically manage uncertainty in the input data.
10 Automated methods for handling uncertainty in the input data
11 remains an outstanding technical issue and constitutes a
12 significant Navy problem as well as a scientific and
13 industrial challenge.

14 Uncertainty refers to being in a condition of doubt.
15 This is contrasted to a condition of certainty or being
16 definite, known, or specific. In an information processing
17 context, uncertainty can be thought of as having a lack of
18 definitive knowledge necessary to describe the process.
19 Uncertainty in the input may result due to many causes
20 including but certainly not limited to measurement noise,
21 gaps in sensor information, sensor bias, inadequate number
22 or placement of sensors, transmission noise or limitations,
23 and the like. While most signals are measured within a
24 tolerance, e.g., ten volts plus or minus one hundred micro
25 volts, an uncertain signal is not known within the normal
26 tolerances and may be so uncertain that normally used sensor
27 tolerances are meaningless. Thus, while a tolerance of one

1 hundred micro volts might be an accepted tolerance for an
2 accurate signal in a particular application, an uncertain
3 signal might vary by several volts or by more than one
4 thousand times the normal accepted tolerance for the signal,
5 thus making the signal quite uncertain in a particular
6 application. Thus, a known or definite signal might be ten
7 volts, an uncertain signal might be representable only as a
8 possible value between eight and twelve volts. As another
9 example of uncertain input, a sonar system working in a
10 multipath environment may send out a sonar pulse and receive
11 two or three sonar pulses in return. All three sonar pulses
12 may be received within a time frame that would present
13 reasonable distance/direction information for receipt from
14 the intended target. Therefore, there is uncertainty
15 associated with the acoustic propagation path for each
16 returned sonar pulse. As another example, it may be
17 possible to get an approximate targeting solution value
18 immediately since a decision for action may need to be taken
19 now, whereas in time a more precise value will be available.
20 This situation arises in a target motion analysis where a
21 fundamental property of bearings-only target motion analysis
22 is that contact range is not observable for a single-leg
23 ownship motion (wherein a leg is defined as a time interval
24 of constant platform velocity). The range becomes
25 observable only after an ownship maneuver followed by a
26 second leg of motion that therefore introduces a time-
27 latency in the estimation process owing to the necessity of

1 collecting sufficient data on all legs of motion. Thus,
2 there are many different scenarios of types of uncertainty
3 that will depend on each different situation.

4 As a general matter, an information processing system
5 such as a combat control system or other typical control
6 system will produce one or more specific or definite control
7 signals in response to the input data. A representative
8 example might include a tactical picture display that might
9 show a submarine in relation to other targets. Another
10 example might include a control for a motor to adjust rudder
11 position. This is also true of a fuzzy logic-based control
12 system. Fuzzy logic control systems have been employed
13 successfully employed in various applications. Moreover,
14 fuzzy logic controllers have been successfully applied and
15 demonstrated in underwater combat control systems such as,
16 for example, a conditioned fuzzy logic controller for an
17 acoustic vehicle intercept guidance system.

18 A prior art fuzzy inference system has three basic
19 components. The fuzzifier converts discrete or crisp input
20 numbers to fuzzy logic membership values that describe a
21 qualitative description of the discrete input in semantic
22 terms. For instance, a numerical sensor value such as might
23 be produced from a sensor voltage might be converted from
24 its discrete, known, or specific value to a fuzzy logic
25 membership value in a qualitative class, e.g., low, medium,
26 or high. The output of the fuzzifier is represented in
27 these membership values, and comprises the fuzzy input

1 membership values. The fuzzifier is not designed to handle
2 an input that is inexact and has a possibility of varying
3 throughout a range of values.

4 The input membership values are used by an inference
5 engine. The inference engine employs a knowledge base of
6 rules that permit one or more inferences, and subsequent
7 aggregation of all the output membership functions from the
8 rules that are triggered by the fuzzy input membership
9 values. Thus, the inference engine maps the fuzzy input
10 membership values to a single fuzzy output set based on
11 applicable rules from the knowledge base.

12 The defuzzifier converts the fuzzy output set to a
13 crisp, discrete, particular output value for subsequent
14 usage, e.g., the controller output in a feedback system. The
15 crisp output is representative of the fuzzy output set and
16 might be analogous to the expected value in a probability
17 distribution.

18 In summary, a conventional fuzzy system does not have
19 the mechanism to handle an uncertain input, yet such inputs
20 are typically encountered in practice, e.g., data
21 integration for submarine combat control. Simply taking an
22 average, making an estimate, or calculating a normal value
23 and using the discrete value so determined as input to the
24 fuzzy logic inference system will limit the information that
25 is available about the uncertainties, and thereby reduce the
26 likelihood of making the best possible decision.
27 Consequently, there remains a need for a fuzzy logic-based

1 information processing system that can handle uncertain
2 input. Those skilled in the art will appreciate the present
3 invention that addresses the above and other problems.

4 5 SUMMARY OF THE INVENTION

6 Accordingly, it is an object of the present invention
7 to provide an improved system and method for processing data
8 using fuzzy logic.

9 It is another object of the present invention to use a
10 fuzzy logic system that is capable of processing either
11 certain or uncertain data.

12 It is yet another object of the present invention to
13 provide an improved control system and method.

14 It is yet another object of the present invention to
15 provide an improved tactical picture and decision support
16 system.

17 These and other objects, features, and advantages of
18 the present invention will become apparent from the
19 drawings, the descriptions given herein, and the appended
20 claims.

21 In accordance with the present invention, a fuzzy logic
22 system for processing information including uncertain
23 information is disclosed. At least one input provides
24 information that is indicative of one or more physical
25 phenomena. The input is representable by an input set that
26 describes a range of possible values related to the one or
27 more physical phenomena. When a precise value for the input

1 is not available such that the input value is uncertain,
2 then input set is representable mathematically by a first
3 map of possible values related to the one or more physical
4 phenomena.

5 The fuzzy logic system comprises an extensor for
6 operating on the input set to produce an operated set of
7 values that may be represented by an extension of the first
8 map using what might be called an extensor or cylindrical
9 extensor. An inference engine for the fuzzy logic system
10 includes a plurality of rules related to the one or more
11 physical phenomena. The inference engine is operable for
12 manipulating the operated set of values using the plurality
13 rules for producing a conditioned set of values. A
14 projector or retro-projector is provided for producing an
15 output signal from the conditioned set of values. The
16 output signal may be used for various purposes such as in
17 displaying a picture such as a tactical picture or providing
18 other decision support assistance. The output signal could
19 also be used in a control system such as a guidance and
20 navigation control system, or the like.

21 In one embodiment of the invention, the rules may be
22 represented mathematically by a second map. The conditioned
23 set may be represented as a third map that is effectively
24 formed by an intersection of the extended first map and the
25 second map. The projector produces a signal that may be
26 represented as a mapping with one dimension of the third map

1 being collapsed and provided such that the output signal is
2 in the desired terms.

3 A method is provided for a control system such as for a
4 combat control system for utilizing uncertain input data
5 that has an uncertain value that is contained within a range
6 of possible values. The uncertain input data is
7 representative of physical phenomena and may be derived from
8 multiple different physical phenomena or may be
9 representative of some particular phenomena. For instance,
10 an input representative of a particular target or platform
11 such as a ship or submarine may be derived from information
12 such as sonar signals that indicate the frequency of
13 propeller rotation and/or the number of propellers detected
14 and so forth. The information may be inconclusive about
15 what type of platform is detected but may provide a range of
16 possibilities as discussed in more detail subsequently.

17 The uncertain input data is presented for use in a
18 fuzzy logic system with the representation providing a set
19 of possible values for the input data without designating a
20 specific value for the uncertain input data. Rules are
21 provided for the fuzzy logic system in terms related to the
22 uncertain input data such as giving possibilities of the
23 likelihood of diesel or nuclear operation and the associated
24 speeds thereof. An output is then inferred from the fuzzy
25 logic system using the set of possible values for the input
26 data and the rules. The uncertain input data may be
27 described by mathematical values although it is possible

1 also that linguistic rules and/or symbols and/or other types
2 of logic could be used. Similarly the rules for the fuzzy
3 logic system may be represented in terms that may be
4 described by a second set of mathematical values although,
5 as discussed above, it is possible that other types of
6 representations could be made. A third set of mathematical
7 values is produced based on the first set and the second
8 set. In a presently preferred embodiment, the third set
9 effectively comprises an intersection of the first set and
10 the second set. The output from the fuzzy logic system is
11 then used for various purposes such as for providing a
12 tactical picture.

13 The fuzzy logic system of the present invention could
14 be used in a control system, such as a combat control
15 system, that comprises at least one sensor for producing a
16 sensor signal used to produce input information for the
17 control system. The fuzzy logic inference system of the
18 control system is operable for receiving the input
19 information when the input information is precise and also
20 when the input information is uncertain such that a
21 representation of the information is produced when the input
22 information is precise and also when the information is
23 uncertain. Thus, the system can handle either uncertain or
24 certain information. When the input information is
25 uncertain, the representation is descriptive of a range of
26 possible values for the input information and the fuzzy
27 logic inference system is operable for comparing the

1 representation to a set of rules to produce an output
2 control signal. An extensor or cylindrical extensor is used
3 for operating on the input information to produce a first
4 map by introducing at least one additional dimension to the
5 input information. The at least one additional dimension is
6 related to the set of rules. It will be noted that the
7 present invention may be used with many dimensions such that
8 the steps of operation may not always be easily visualized.
9 The rules are represented by a second map that includes the
10 at least one additional dimension. The fuzzy logic
11 inference system is operable for comparing the first map to
12 the second map to produce a third map. A projector or retro
13 projector may be used for operating on the third map to form
14 a projection onto a dimension for the output control signal.

15 The output control signal, as yet another example,
16 may be used in a decision support system to provide a range
17 of possibilities for aiding the decision maker.

18

19 BRIEF DESCRIPTION OF THE DRAWINGS

20 A more complete understanding of the invention and many
21 of the attendant advantages thereto will be readily
22 appreciated as the same becomes better understood by
23 reference to the following detailed description when
24 considered in conjunction with the accompanying drawings
25 wherein corresponding reference characters indicate
26 corresponding parts throughout several views of the drawings
27 and wherein:

1 FIG. 1 is a block diagram of a fuzzy logic information
2 processing system in accord with the present invention;

3 FIG. 2 is a block diagram of a fuzzy logic inference
4 system as might be used in the fuzzy logic information
5 processing system of FIG. 1;

6 FIG. 3 is a graphical representation of the process of
7 mapping an uncertain input through a fuzzy logic inference
8 system to the desired output.

9 FIG. 4 is a map of rules for a particular illustrative
10 inference system in accord with the present invention;

11 FIG. 5 is an arbitrary graph descriptive of a bell or
12 Gaussian curve that shows a set of possible values for the
13 input for which any particular value in the set is
14 uncertain;

15 FIG. 6 is a map of the uncertain data of FIG. 5 that
16 has been extended into another dimension by an extensor or
17 cylindrical extensor in accord with the present invention:

18 FIG. 7 is a map of the combination of the map of FIG. 4
19 and the map of FIG. 6;

20 FIG. 8 is an output for the system that shows the
21 output in the desired terms and also compares a fixed value
22 input with the results of an uncertain input; and

23 FIG. 9 discloses one of many possible tactical displays
24 in which the output of the present invention may be used.

1 BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

2 Referring now to the drawings and more specifically to
3 FIG. 1, there is shown an embodiment of an information
4 processing system in accord with the present invention.
5 Fuzzy logic processing system 10 illustrates that stimulus
6 11 is detected and its characteristics are relayed to output
7 36 using fuzzy logic when uncertainties related to stimulus
8 11 and/or other aspects of the input exist. Thus, the
9 problem involves uncertainties that propagate through system
10 10. Stimulus 11 may be one or more physical phenomena of
11 some type such as propeller rotation frequency or pattern
12 and may produce one or more of signals 12, 14 and 16. One
13 or more of signals 12, 14, and 16 are received by remote
14 organic sensor 18, organic sensor 20, and/or off board
15 sensor 22, respectively. Signals 12, 14 and 16 could be
16 descriptive or related to a natural physical phenomena such
17 as acoustic or electromagnetic waves intercepted by sonar or
18 radar receivers. Remote organic sensor 18 and organic
19 sensor 20 use in this case the definition of organic as
20 being sensors associated with the body or craft in that the
21 sensors are either attached to craft or are remote but
22 controlled by the craft. Organic sensors can therefore
23 include a remotely launched probe, sonar, radar, or any type
24 of device which detects physical phenomena such as, for
25 instance, detection of another object for tracking purposes.
26 Off board sensor 22 is independent of the body or craft and
27 can transmit the data relating to stimulus 11 which, as

1 discussed above, may represent numerous different types of
2 stimuli. The data collected by sensors 18, 20 and/or 22 are
3 transmitted through respective possible transmission paths
4 24, 26 and 28. These paths may have physical imperfections
5 which can cause gaps in the data, as depicted by uncertainty
6 30. Uncertainty 30 could arise in many ways and at many
7 places in the processing system and is pictured in a
8 specific place only for convenience. For instance, sensors
9 18, 20 and 22 may not have detected all signals or have
10 received erroneous information, thus more uncertainty is
11 present. There may be a time lag problem as discussed
12 subsequently. It will be understood by those skilled in the
13 art that there are virtually an infinite number of reasons
14 that can arise to cause uncertainty within the input data.
15 Thus, the result is that data with inherent uncertainties is
16 received by fuzzy inference system 32 from one or more of
17 signal paths 24, 26, and/or 28. While prior art fuzzy
18 inference systems cannot handle uncertain data, the
19 inference system of the present invention can handle
20 uncertain or certain data, as explained in more detail
21 hereinafter, using rules 34 within fuzzy inference system 32
22 to yield output 36, that may be used for producing a
23 tactical picture, guidance presets, motor control, decision
24 support, and the like.

25 A presently preferred embodiment of fuzzy inference
26 system 32 is shown in greater detail in FIG. 2. The
27 collective data sent over paths 24, 26 and/or 28 detected by

1 sensors 18, 20 and 22 contains uncertainty as represented
2 graphically by the region of fuzzy input 38 wherein it is
3 uncertain what the precise value of fuzzy input 38 is.
4 Fuzzy input 38 is mathematically represented by $\mu_a(x)$, with
5 collective data that varies about the line $x = a$. Thus,
6 whereas the prior art fuzzy inference system would require a
7 precise input, such as $x = a$, the system of the present
8 invention can handle the uncertain input where it is known
9 only that input x varies about a to form a set of possible
10 values described by the function $\mu_a(x)$. The region or set
11 of values described by $\mu_a(x)$ is arbitrarily selected in the
12 present example and could take on many different forms or
13 shapes. For the present explanation purposes, a Gaussian
14 bell type curve distribution describes the region of
15 possible values for the input as shown by FIG. 5. The input
16 could be in the form of a square wave, pulse, multiple
17 sections, or other shapes. While the example given herein
18 uses a numerical characterization of uncertain data, it will
19 be understood that the present invention is not limited to
20 numerical characterization and could also be used with other
21 types of symbolic characterizations of data as might be used
22 for the particular problem to be solved.

23 Fuzzy input 38 is received by fuzzy inference system 32
24 and operated on by extensor or cylindrical extensor 40.
25 Cylindrical extensor 40, in the present example, operates on
26 fuzzy input 38 to provide an extension of fuzzy input 38 in
27 the x, y plane to form extension 41, as represented by

$$\mu_a(x, y) = \mu_a(x) \forall y. \quad (1)$$

Extension 41 might be graphically described as adding an extra dimension or, in this case, a third dimension. However, it will be understood that depending on the complexity of the problem many dimensions may be involved so that a visually understandable picture of an extended bell curve as might be exemplified by FIG. 6 may not always be available for every problem. The modified data or extension 41 is made available for fuzzy mapping section 42 for further operation. Fuzzy section 42 is derived from rules 34 and is mathematically represented by $F(x, y)$ as might be visualized in one example by FIG. 4 discussed below. Fuzzy mapping section 42 operates on extension 41 to yet again amend the data to form the conditioned data or surface 43 or $F_c(x, y)$ which might be visualized in one example as shown in FIG. 7. The whole operation performed by fuzzy mapping 42 can be described as

$$F_c(x, y) = \min[F(x, y), \mu(x, y)]. \quad (2)$$

In the example of the present case, this can be verbally, symbolically, or linguistically restated as the graphical intersections of rules 34 and the output of cylindrical extensor 40 to form conditioned surface 43. Now retro-projector 44 receives the $F_c(x, y)$ or conditioned surface 43 and transforms it into fuzzy output 46 or $M_{\mu_a}(y)$ as might be graphically represented as shown in FIG. 8. This process can be symbolized by the formula

$$M_{\mu_a}(y) = \max_x [F_c(x, y)]. \quad (3)$$

1 values been known as required in a prior art fuzzy logic
2 inference system, line 60 would accurately depict this
3 output. Finally, the data is transformed back into usable
4 form by projecting the graphical image into the desired
5 units by removing a dimension, represented by line 62. This
6 is the fuzzy output $M_{\mu_a}(y)$, given by

$$7 \quad M_{\mu_a}(y) = \max_x [F_c(x, y)]. \quad (5)$$

8 FIG. 4-9 give a possible example of a step-by-step
9 graphical representation of the process of fuzzy inference
10 system 32 using more specifically an example of tracking a
11 platform such as a submarine or ship in relation to another
12 platform. It will be understood that this is one example
13 only given for explanatory purposes only. The invention is
14 not intended to be limited by this example and may be used
15 in different applications and conditions, including, but not
16 limited to: medical, industrial, marine, warfare,
17 exploration, and numerous other settings.

18 Referring now to FIG. 4 and subsequent figures, the
19 axes x , y and z are defined as class axis 66, membership
20 axis 68 and speed axis 74, respectively. The example is
21 based upon a two rule, one input, one output fuzzy inference
22 system, which will provide target speed based upon detected
23 class. The target will have a higher speed if it has a
24 nuclear engine than if it has a diesel engine. Class axis
25 66 ranges from zero to one, with zero denoting diesel and
26 one representing nuclear. Membership axis 68 also ranges
27 from zero to one, with zero designating no membership and

1 one indicating one hundred percent membership in the
2 specified class. Therefore, a target is diesel if class
3 equals zero and membership equals one, whereas a target is
4 nuclear if class equals one and membership equals one.
5 Speed axis 74 ranges from zero to forty, or the range of
6 speed of the target in knots. A nuclear engine target is
7 more likely to be traveling in the range of 15 to 30 knots
8 as compared with a diesel engine target with a speed more
9 likely in the range of 5 to 15 knots. The rules can be
10 summed up as the following: (1) if class is diesel, then
11 speed is low and (2) if class is nuclear then speed is high,
12 as depicted by the three dimensional rule graph 70
13 represented by the function $F(x,y)$. The rules for the
14 present example are graphically displayed as a set, map,
15 figure, or curve as shown in FIG. 4. It will be understood
16 that while the map or set of values indicated may be easily
17 visualized in three dimensions as in the example of FIG. 4,
18 other systems of rules, inputs, and/or outputs may use many
19 dimensional or n-dimensional maps that are not so easily
20 visualized.

21 The example further continues with the fact that
22 sensors and/or other intelligence have detected a target
23 with class equal to about 0.3 with some amount of
24 uncertainty. The sensors used for this purpose might
25 conceivably be sonar receivers that detect a propeller speed
26 or type of sound or the like. The result of the detected
27 input is graphically depicted in FIG. 5 with an input that

1 is uncertain but has possible values about point 64,
 2 representing $x=0.3$. For this example, a Gaussian membership
 3 function, graph, map or set 72 describes the fuzzy input.
 4 The target is not described exactly in class equal to 0.3,
 5 but rather is described as a possible value within the area
 6 under the curve but uncertain as to exactly what that value
 7 is. If the input were definite, such that the information
 8 was exactly 0.3, then the present invention would also
 9 operate to handle that situation in the same manner as
 10 discussed below. Function 72 would then simply be a
 11 straight line at 0.3. Thus, the present invention is
 12 operable with both definite and uncertain data. However
 13 assuming the input to be uncertain, then Gaussian membership
 14 function 72, for an example only, may have formula equal to

$$15 \quad \mu_{0.3}(x) = \exp \left[-\frac{(x-0.3)^2}{2*0.05^2} \right] \quad (6)$$

16 In accord with the system and method of the present
 17 invention, Gaussian membership function 72 is extended onto
 18 speed axis 74 to make cylindrical extension map, function,
 19 set or graph 76 as shown in FIG. 6, depicting the operation
 20 of extensor or cylindrical extensor 40. Thus, the input is
 21 extended onto at least one dimension characteristic of the
 22 rules. Cylindrical extension map, set, function or graph 76,
 23 represented by $\mu_{0.3}(x,y)$, is obtained by the mathematical
 24 expression discussed above, i.e.,

$$25 \quad \mu_a(x,y) = \mu_a(x) \forall y. \quad (7)$$

1 Fuzzy mapping section 42 operates on cylindrical
2 extension map, set, or graph 76 and rule map, set, or graph
3 70. In the present example an intersection is found as the
4 result of this operation that provides map, set, or
5 conditioned surface graph 78 as shown in FIG. 7.
6 Conditioned surface map, set or graph 78, noted as $F_c(x,y)$,
7 was obtained in accord with the equation expressed above,
8 i.e.,

$$9 \quad F_c(x,y) = \min[F(x,y), \mu(x,y)]. \quad (8)$$

10 In FIG. 8, conditioned surface graph 78 is fed into the
11 retro-projector where the graph is projected onto speed axis
12 74 and possibility axis 84. A dimension is reduced in
13 accord with the desired output terms resulting in two
14 dimensional output fuzzy data 80. Interpretation of this
15 graph states that the target is more likely to be traveling
16 about ten knots, but still has the possibility of going
17 about twenty to thirty knots, though this is not as likely.
18 Line 82 is the graph obtained had exact values been taken
19 with $x=0.3$, resulting in the uncertainty obtained using
20 fuzzy input being deleted and never taken into account. Had
21 this been done as would have been a plausible solution for
22 prior art fuzzy logic inference systems that require an
23 exact input, then the likelihood would have been
24 significantly greater that the speed in the range of about
25 ten knots. Thus, a decision maker might have been more
26 likely to make a decision that committed too early a
27 decision based on the target speed being in the range of

1 about ten knots. A better decision would have been to wait
2 as long as possible before committing due to the increased
3 possibility that the speed was in the range of from fifteen
4 to thirty knots when the uncertainty of the input was
5 included in the calculation.

6 In a bearings-only target motion analysis problem it is
7 necessary to estimate contact location and motion parameters
8 using a time series of bearing measurements. A fundamental
9 problem of the bearings-only target motion analysis
10 application is that the contact range is not observable for
11 a single-leg of ownship motion wherein a leg is defined as a
12 time interval of a constant platform velocity, such as that
13 of a ship or submarine. A time lag is therefore introduced
14 into the estimation process owing to the necessity of
15 collecting sufficient data on all legs of motion. In some
16 cases rapid estimates are needed even though they may be of
17 poorer quality due to the time urgency of the tactical
18 situation. Tactical map 86, shown in FIG. 9, is one
19 possible resulting use of the data obtain about the target.
20 The fuzzy characterization of contact speed as discussed
21 above using the fuzzy logic inference system output as shown
22 in FIG. 8 is used to produce an enhanced area of uncertainty
23 description for the single leg target motion analysis.
24 Tactical map 86 shows in Kyards the target's suspected
25 contact end-point position 96 in relation to observer 94.
26 Tactical map 86 also displays area 88, depicted 50%
27 possibility of the target end point being in that area.

1 Area 90 depicts 85% confidence, and area 92 denotes 98%
2 confidence of the target being within those borders. For
3 reference, location 98 is the actual target end point
4 position. While end-points of the likely tracks are
5 displayed in tactical map 86, the various possible tracks
6 with the most likely track may also be viewed with a colored
7 intensity weighting for the likelihood of the various
8 tracks.

9 In summary, the present invention is operable for using
10 uncertain data as described as an example only in FIG. 5.
11 This data is operated on to produce data with one or more
12 dimensions added as shown in this example in FIG. 6. The
13 rules are graphically displayed in this example in FIG. 4.
14 The result of operating on the extended data with the rules
15 is shown in FIG. 7. This data is then projected onto the
16 units desired for output as shown in FIG. 8. The resulting
17 output may then be used in a control system as desired and
18 can be seen in the tactical display of FIG. 9.

19 It will be understood that many additional changes in
20 the details, materials, steps and arrangement of parts,
21 which have been herein described and illustrated in order to
22 explain the nature of the invention, may be made by those
23 skilled in the art within the principle and scope of the
24 invention.

1 Attorney Docket No. 79238

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3 FUZZY LOGIC BASED SYSTEM AND METHOD FOR INFORMATION

4 PROCESSING WITH UNCERTAIN INPUT DATA

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6 ABSTRACT OF THE DISCLOSURE

7 A fuzzy logic information processing system and method
8 are disclosed that may be used not only with known or
9 definite data input but also with uncertain data input. The
10 uncertain data input may be represented by a set of values
11 wherein the possibility of any particular or specific value
12 within the set being the true or accurate value is
13 uncertain. The preferred embodiment of the system provides
14 for an extensor to extend or map a representation of the
15 uncertain data into at least one additional dimension
16 related to dimensions of a set of rules used for making
17 fuzzy logic inferences. The set of rules may be provided
18 effectively in a mapped or graphed form. The set of rules
19 and uncertain data are combined, for instance by locating
20 intersection regions, to produce an output set that may be
21 also be described as a map or plot. In a presently
22 preferred embodiment the uncertain inputs and rules are
23 represented mathematically or symbolically and then operated
24 on to produce an output set. A projector then projects the
25 output set to the desired output dimension as an output for
26 the system. The system output may then be used for control
27 purposes such as, for example only, a combat control system

- 1 to provide a tactical picture, decision aid, presets for a
- 2 guidance system, or the like.