An apparatus (10) may implement a method (160) for creating (162) a data-domain sampled network (206). In certain embodiments, a method in accordance with the invention may define (166) a data domain, provide (172) points in a data-domain space or sub-space, followed by analyzing (174) data in the data domain (100). Analysis (174) may involve selecting (175) the dimensions or variables of interest, evaluating (176) or determining (176) the cycles per dynamic range, selecting (177) an interpolation method, and selecting (178) a number of sample points (223) in each respective dimension (227, 228). Providing (180) a data-domain network (206) typically includes applying (184) multidimensional sampling theory to a native data domain (100). Calculating (188) waits for this by an interpolation module (212) specifies the data-domain network in its native domain (100).
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DATA-DOMAIN SAMPLED NETWORK

BACKGROUND OF THE INVENTION

1. The Field of the Invention

The present invention relates to data analysis, and more particularly, to novel systems and methods for mapping correlations of data while maintaining data in an original data-domain rather than transforming the data into other domains for manipulation.

2. The Relevant Technology

In the disclosure of United States Patent Number 5,796,922 (hereinafter the "'922 patent") issued August 18, 1998 to Smith and directed to a Trainable, State-Sampled, Network Controller, several very useful analysis techniques are presented. In addition to the matrix algebra methodologies, very useful properties in a state-sampled domain are relied upon. For example, by reliance upon the uncoupled, independent nature of variables in the state domain, simplified systems of equations may be formulated and readily solved. However, if data is highly coupled, the presumption of independence or uncoupling between variables is highly inaccurate.

Also, the '922 patent relies on transformations into, and subsequent analysis in, the state-space domain. Such transformations into a state-space typically provide analytical simplicity. However, in many actual situations encountered, information regarding coupling between dimensions is lost by the required transformations.

Another issue raised when one reviews the '922 patent is that of "previous knowledge" of the form of equations. In control systems, classical control theory provides a plethora of terms having forms well understood for modeling various configurations of hardware or other control environments. In other classes of problems encountered in the real world, the forms of equations are not necessarily known. Moreover, in many situations, even when the form of equations is known, or the equations themselves are exactly known, absolutely intractable calculation complexity prohibits actual solutions of the governing equations.

Thus, what is needed is a method that does not require independence of variables, but which can rather accommodate, even capture and interpret, the coupled relationships between different variables (dimensions) in a data-domain. Also needed is a method that does not require transforms, particularly transforms that may lose information from the original data-domain. Another need exists for a simplified, virtually single-step, method for mapping an output or solution surface in a multidimensional data space from input data directly without having to undergo complex calculations, encounter impossible calculations, or know a priori the form of a governing equation.
Thus, what is needed is a system for simply and rapidly correlating outputs and inputs related to data, in their original domains, without requiring an intermediate transformation. In classical methods, this is often impossible. Complexity may render problems intractable. Numerical methods, in which computerized algorithms for approximation are sufficiently accurate, or can be made sufficiently accurate for all practical purposes, are desirable. Thus, what is needed is a method by which data can be maintained in its original domains, and in which some correlation between data parameter of interest (e.g. inputs and outputs, or independent variables and dependent variables) can be related quickly, accurately, continuously, and simply.

**BRIEF SUMMARY OF THE INVENTION**

In view of the foregoing, it is a primary object of the present invention to provide a method and apparatus for moving between dimensions of a data-domain, e.g. to correlate inputs and outputs in a solution space without losing information from the data-domain through transformations.

It is an object of the invention to provide a method and apparatus effective to amalgamate multidimensional data, combining data sets or streams without requiring or falsely assuming independence or uncoupling between variables (dimensions in the data-domain).

It is an object of the invention to provide a method and apparatus for preserving information in interdependent variables from different dimensions in the data-domain.

It is an object of the invention to provide simplified data processing, analysis, and the like wherein data may be correlated to provide useful relationships (e.g. solutions, input/output relations) in a single algorithmic operation, particularly without loss of continuity of any dimension of the data-domain.

It is an object of the invention to do the foregoing without requiring *a priori* knowledge of the equations or forms of equations relating variables to one another.

Consistent with the foregoing objects, and in accordance with the invention as embodied and broadly described herein, an apparatus and method are disclosed, in suitable detail to enable one of ordinary skill in the art to make and use the invention. In certain embodiments of methods and apparatus in accordance with the invention, data may be manipulated or used in a data network of data points (as opposed to a hardware computer network, over which operations may proceed) in an original data-domain, without transformation into a domain that would lose important properties of the data. For example, coupling, continuity of variables, and continuity of variables derivatives may be maintained.
BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and features of the present invention will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only typical embodiments of the invention and are, therefore, not to be considered limiting of its scope, the invention will be described with additional specificity and detail through use of the accompanying drawings in which:

Figure 1 is a schematic block diagram of an apparatus in accordance with the invention suitable for operating within a computer system over networks;

Figure 2 is a schematic diagram of a sensor system illustrating coupled data generation for a data domain sample network;

Figure 3 is a schematic diagram of a data domain;

Figure 4 is a schematic diagram of a data domain illustrating a surface representing one parameter or value set within the data domain of Figure 3;

Figure 5 illustrates curves of intersection at constant values of a variable or dimension in a data domain;

Figure 6 illustrates a schematic block diagram of a process for creating and using a data domain sample network;

Figure 7 is a schematic block diagram of data structures for implementing the invention in a memory of a computer;

Figure 8 is a schematic block diagram of the processes and data structures for implementing the apparatus and method of Figures 1-7; and

Figure 9 is a schematic representation of interpolation of a point on a surface of interest in a data domain of interest according the method and apparatus of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of the embodiments of the system and method of the present invention, as represented in Figures 1 through 9, is not intended to limit the scope of the invention. The scope of the invention is as broad as claimed herein. The illustrations are merely representative of certain, presently preferred embodiments of the invention. Those presently preferred embodiments of the invention will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout.

Those of ordinary skill in the art will, of course, appreciate that various modifications to the details of the Figures may easily be made without departing from the essential characteristics of the invention. Thus, the following description of the Figures
is intended only by way of example, and simply illustrates certain presently preferred embodiments consistent with the invention as claimed.

Referring to Figure 1, an apparatus 10 may implement the invention on one or more nodes 11, (client 11, computer 11) containing a processor 12 or CPU 12. All components may exist in a single node 11 or may exist in multiple nodes 11, 52 remote from one another. The CPU 12 may be operably connected to a memory device 14. A memory device 14 may include one or more devices such as a hard drive or non-volatile storage device 16, a read-only memory 18 (ROM) and a random access (and usually volatile) memory 20 (RAM).

The apparatus 10 may include an input device 22 for receiving inputs from a user or another device. Similarly, an output device 24 may be provided within the node 11, or accessible within the apparatus 10. A network card 26 (interface card) or port 28 may be provided for connecting to outside devices, such as the network 30.

Internally, a bus 32 may operably interconnect the processor 12, memory devices 14, input devices 22, output devices 24, network card 26 and port 28. The bus 32 may be thought of as a data carrier. As such, the bus 32 may be embodied in numerous configurations. Wire, fiber optic line, wireless electromagnetic communications by visible light, infrared, and radio frequencies may likewise be implemented as appropriate for the bus 32 and the network 30.

Input devices 22 may include one or more physical embodiments. For example, a keyboard 34 may be used for interaction with the user, as may a mouse 36 or stylus pad 37. A touch screen 38, a telephone 39, or simply a telephone line 39, may be used for communication with other devices, users, or the like. Similarly, a scanner 40 may be used to receive graphical inputs which may or may not be translated to other character formats. A memory device 41 of any type (e.g. hard drive, floppy, etc.) may be used as an input device, whether resident within the node 11 or some other node 52 on the network 30, or from another network 50.

Output devices 24 may likewise include one or more physical hardware units. For example, in general, the port 28 may be used to accept inputs and send outputs from the node 11. A monitor 42 may provide outputs to a user for feedback during a process, or for assisting two-way communication between the processor 12 and a user. A printer 44 or a hard drive 46 may be used for outputting information as output devices 24.

In general, a network 30 to which a node 11 connects may, in turn, be connected through a router 48 to another network 50. In general, two nodes 11, 52 may be on a network 30, adjoining networks 30, 50, or may be separated by multiple routers 48 and multiple networks 50 as individual nodes 11, 52 on an internetwork. The individual nodes 52 (e.g. 11, 52, 54) may have various communication capabilities.

In certain embodiments, a minimum of logical capability may be available in any node 52. Note that any of the individual nodes 11, 52, 54 may be referred to, as may all
together, as a node 11 or a node 52. Each may contain a processor 12 with more or less of the other components 14-44.

A network 30 may include one or more servers 54. Servers may be used to manage, store, communicate, transfer, access, update, and the like, any practical number of files, databases, or the like for other nodes 52 on a network 30. Typically, a server 54 may be accessed by all nodes 11, 52 on a network 30. In general, herein, any node 11, 52 accessible to obtain information or files may be referred to as a server. Thus, a "web site" available to users of an internetwork 50 may be thought of as a server 54, serving whatever it serves. Other special functions, including communications, applications, directory services, and the like may be implemented by an individual server 54 or multiple servers 54. An node 11, 52 may be a server 54.

In general, a node 11 may need to communicate over a network 30 with a server 54, a router 48, or other nodes 52. Similarly, a node 11 may need to communicate over another network (e.g. like or unlike the network 30) in an internetwork 50 connecting with nodes 52 remote from the network 30. Likewise, individual components 12-46 may need to communicate data with one another. A communication link may exist, in general, between any pair of devices.

Referring to Figure 2, a system 60 for observing an object 62 moving in an azimuthal direction 64 and an elevation direction 66 is illustrated. In the illustration of Figure 2, radiation 68 (an image) proceeds from the object 62, which may, for example, be the sun 62. In the illustrated embodiment, a sensor suite 70 includes detectors 72 (azimuthal sensor 72) and 74 (elevation sensor 74) that detect radiation (images) reflecting motion in dimensions orthogonal to one another.

The sensors 72, 74 have connections 76, 78 or connecting data lines 76, 78 for connecting the sensors 72, 74, respectively, to a data acquisition system 80. The data acquisition system 80 may execute digital signal processing or other pre-processing. Alternatively, the data acquisition system 80 may simply record parameters output by each sensor 72, 74.

In turn, the data acquisition system 80 may connect to an external computer 11 by a cable 82 or other connection 82. The connection 82 may provide both data from the data acquisition system 80 to the computer 11, and controlling data to the data acquisition system 80 from the computer 11.

In general, the computer 11 may be connected to a network 84 in order to provide raw data, pre-processed data, or completely analyzed data from the data acquisition system 80 to other nodes on the network 84. As a practical matter, with networks proliferating, the network 84 may be a local area network or an internetwork and may provide input signals to the computer 11 for controlling the data acquisition system 80, or may simply be a user of data, provided by the computer 11 and representing or reflecting the data from the data acquisition system 80.
Each of the sensors 72, 74 has a “line” of sight 86, 88 toward the object 62. In the illustrated embodiment, an aperture system 90 provides a mask 92, an azimuthal aperture 94, and an elevation aperture 96, in order to isolate the data reflecting motion of the object 62 in the azimuthal 64 and the elevation direction 66. Nevertheless, as a practical matter, motion of the object 62 in any direction 64, 66 effects the radiation 68 passing through the respective aperture 94, 96 to be ultimately received by the respective sensor 72, 74. As a result, the data recorded by the data acquisition system 80 for each of the sensors 72, 74 is actually coupled. In fact, all motions of the object 62 affect the radiation 68 detected by both sensors 72, 74. The example of Figure 2 is merely a simplified example in two dimensions. In general, a system of any number of dimensions may exist.

In a method and apparatus in accordance with the invention, the data provided by the sensors 72, 74 to the data acquisition system 80 need not lose the information stored in the coupling relationship. Mathematically, partial differential equations exist to describe phenomena in which variables or dimensions in a space of interest are not independent.

To the extent that data received on multiple channels of a data acquisition system 80 is independent, then information will not be lost by assuming a lack of coupling or an independence between the channels. However, in the example of Figure 2, assuming that data recorded by the two sensors 72, 74 in the data acquisition system 80 is separable by channels is an incorrect assumption. Storing and analyzing the data by individual channels or uncoupled transformations and assuming independence will destroy the coupling information.

Accordingly, no assumption of linearity or independence is required with respect to data. Instead, the data is maintained in its native domain 100 (see Figure 3). By maintaining data in its native domain 100, distortions or singularities, discontinuities, and the like, need not be introduced by transformations. Instead, the data can be recorded coupled as detected, and an apparatus 10 in accordance with the invention can process the data to determine the correlation between all variables or dimensions in the data domain 100.

In speaking of a data domain 100, one may think of independent and dependent variables naturally. However, in many situations, independence and dependence of variables is not understood or even recognized. Thus, one advantage of an apparatus and method in accordance with the invention is an ability to preserve the information that may be otherwise detectable in the coupling between channels in a data acquisition system 80.

Referring to Figure 3, a data domain 100 may be defined in terms of a first variable 102 or first dimension 102, a second variable 104 or second dimension 104, and a third variable 106 or third dimension 106. Since more than three dimensions are very difficult or impossible to illustrate, the example of Figure 3 relies on three dimension. Nevertheless, no inherent limit exists on the number of dimensions in a data domain 100.
The data domain 100 includes various points 108 in a surface defined by the first
102 and second dimension 104. Corresponding to each point 108, is a value 110 in the
dimension 106. One may naturally desire to think of the first and second dimensions 102,
104 as the independent dimensions, and the dimension 106 of the values 110 as a third and
dependent dimension.

Nevertheless, in accordance with the invention, any dimension 102, 104, 106 may
be selected as a functional or valued dimension, sometimes referred to as a solution-
dimension or a function of interest 110. No presumptions need to be made regarding what
is dependent and what is independent in storing data. Anything that can be detected and
recorded may be stored in a data domain 100. Any practical number of dimensions 102,
104, 106 may be used. Thus, any practical number of variables 102, 104, 106 may be
used in the data domain 100.

Also, although used in the illustration, the increments 112, 114 may be regular,
irregular, and may or may not be known in advance. For example, when a data acquisition
system 80 records data, the data 100 typically is a stream in time. Thus, for every channel
of a data acquisition system 80, some series of points 108, 110 is recorded, one value for
each channel at the time common to all channels in the data stream. Later, in processing,
such as for examination or analysis purposes, and the like, various sub-domains 116, 118
may be defined. Those sub-domains 116, 118 may be defined in terms of increments 112,
114 within the respective dimensions 102, 104.

Referring to Figure 4, the data domain 100 of Figure 3 may be viewed to include
a surface 120 connecting the values 110 in the dimension 106 or functional dimension 106.
It is important to note that the functional dimension 106 is an arbitrary designation. As
a practical matter, the functional dimension 106 may be a dimension suggested by ease of
controlling other variables 102, 104. However, no preconceived notions need to be
entertained regarding dependence and independence of variables 102, 104, 106 except
here as required for clarification in the example.

The surface 120 may extend in all the dimensions 102, 104, 106. A surface
dimension 122 is not the same as a dimension 102. Likewise, the surface dimension 124
is not the same as the dimension 104. Rather, the dimensions 122, 124 are dimensions
along the surface 120, which surface 120 may be projected in the data domain 100 onto
the surface defined by the directions 102, 104, or dimensions 102, 104.

In analyzing the surface 120 in the data domain 100, one may note local maxima
126 and local minima 128. Necessarily, between every maximum 126 and minimum 128,
an inflection point exists. In determining the precision required, according to
multidimensional sampling theory (hereinafter sampling theory), in order to accurately
represent the data domain 100, an evaluation of the numbers of inflection regions 130
determines the required number of sampling points and the degree or other functional
parameters required for any interpolation function.
Referring to Figure 5, a first dimension 134 and second dimension 136 correlate to a third dimension 138 and to one another. In Figure 5, a curve 140 of intersection between a surface 142 represents values in the third dimension 138 at any value of the first and second dimension 134, 136.

A plane 144 of constant dimension 136 corresponds to a fixed value 145 in the second dimension 136. The intersection curve 140 of the plane 144 with the surface 142 represents a curve 140 in the data domain 100 at a constant value 145 of the variable 136 or dimension 136.

Nevertheless, the presence of the plane 144, or the fact that the plane 144 may exist, does not necessarily mean that the plane 144 may be defined. That is, all the variables 134, 136, 138 may be interdependent. A change in any of the variables 134, 136, 138 may alter the structure of the surface 142. In many real problems encountered in the world, involving actual data from physical systems, defining the surface 142 or the curve 140 can be impossible without recourse to numerical approximation schemes.

Tremendous computing power may be required. Tremendous complexity may exist in the relationships. In accordance with the invention, an apparatus and method may define the relationships between the surface 142 and the variables 134, 136 without resort to transformations, assumptions, independence or decoupling, and without highly sophisticated and time-consuming calculations.

The distance 146 may be thought of as a value 146 in the dimension 136. The plane 144 may be thought of as a series of points, of which the point 148 happens to exist in both the plane 144 and the surface 142. The value 150 represents a similar value 138 corresponding to a value of the variable 134 or dimension 134 of zero and a value 152 of the dimension 138, at a value 146 of the variable 136.

For convenience, a grid 154 may define a sub-domain of the data domain 100. The grid 154 may be arbitrary or equally incremented. In accordance with the invention, time, the one variable or dimension whose regularity can usually be controlled, cannot actually be controlled at all. Rather, the variable time is simply incremented, and a data acquisition system 80 is controlled to record channels at a certain specified increment of time. Nevertheless, time cannot actually be controlled. Thus, a data domain may actually contain one or no single, regularly incremented dimension, such as time. All other dimensions may vary with the range of the values of parameters measured in those dimensions.

Nevertheless, in other systems, several parameters in the data-domain may be provided or controlled as inputs. A method and apparatus in accordance with the invention vary drastically from typical state-sampled control networks requiring transformation, and usually implementing state-domain incrementation in some regular fashion. Control of the data in the instant invention is not required.
Referring to Figure 6, a process 160 or method 160 for creating 162 and using 164 a data-domain sampled network is illustrated. Initially, creating 162 a data-domain sampled network, may include providing 165, and optionally defining 166 a data domain 100. A data domain 100 is defined by the dimensions 134, 136, 138, which need not be limited other than to the number of variables or dimensions in which data can be recorded. These may include a definition of the units or properties as well as values in each dimension. A defining step 168 may include optional steps 167, 169. The brackets in the labels indicate that certain processes are optional, although other process steps may also be deleted in selected embodiments.

The defining step 167 is responsible for defining an independent variable domain. The defining step 169 is responsible for defining the functional range. The concepts of domain and range, as well as the concepts of independent variable (input) and dependent variable (output or function) may range from somewhat arbitrary to absolutely and completely arbitrary. Nevertheless, defining 169 a function range typically involves determining a parameter or dimension 138 or interest in which a surface 142 of interest is desired to be observed, not necessarily controlled.

By contrast, defining 167 an independent variable domain, involves selecting other dimensions 134, 136, the influence of which is desired to be parameterized or otherwise quantified or qualified to determine how it relates to or affects the values of the surface 142 or the points 148, 150 within the surface 142 over the dimensions 134, 136.

Thus, the defining step 168 is regarded as optional. Since relationships are inherent in the data domain 166. Those relationships are preserved, and have not been destroyed by manipulation, transformation, and the like, as in prior art systems.

Selecting 170 the dimensions or variables for analysis is responsible for determining which dimensions of the data domain 100 will be relied upon. Providing 172 points in the data-domain space 100, or a sub-space 100, is providing the data of interest, whether dependent, independent, or of unknown relation.

Analyzing 174 data in the data-domain spectrum may include selecting 175 an individual dimension, for evaluation. Thus, the steps 175, 176, 177, 138 may be repeated for each dimension in the data-domain space 100 or data domain 100. Determining 176 the cycles for dynamic range may include evaluating a surface 120, 142 for inflections 130. In general, the frequency, rates of change, number of maxima 126 and minima 128, and so forth will influence the number of data points 148 required in a minimum sample size, as well as influencing the complexity of any interpolation scheme.

Selecting 177 an interpolation method is optional. Sampling theory and interpolation theory have developed optimized techniques. Selecting 177 an interpolation method may be desirable in order to obtain access to an optimized interpolation method and function. This may be helpful for a particular determination 176 of cycles per dynamic range in the dimension 134, 136, 138 of interest.
Selecting 178 a number of sample points in the dimension 134 of interest (the dimension 134 of interest will be used to indicate any dimension 134, 136, etc. in a space 100) is a direct function of the determining step 176. The process 179 continues from the beginning selecting step 175 for all dimensions 134 of interest, including any dimensions 106, 138 of functional surfaces 120, 142, and the like.

Providing 180 a data-domain network, or, more properly data-domain sampled network 180, may begin by selecting 182 an interpolation function. Applying 184 sampling theory to the native data domain 100, or the data domain 100, may suggest types of interpolation functions, as well as an optimal interpolation function of any particular type. For example, the division of sine (x) / x is called a sinc function, and may provide one form of a suitable, even optimized, interpolation function. An interpolation function may be something like the interpolation function 186 of the example of Figure 6. In the example of Figure 6, the interpolation function 186 relates a function to a series of summations of a waiting function multiplied by a value of a function or data point in a particular dimension 134 in a data-domain 100.

Again, the functionality may be somewhat arbitrary, since the correlation between functions in various dimensions 134, 136, 138, or values in various dimensions 134 (dimensions generally 134) is the important factor, and is not presupposed. Details of how to use interpolation functions, may be gleaned from documentation known in the art, and need not be bound to a particular solution in the present invention. Nevertheless, the interpolation function 186 has been found suitable.

Calculating 188 the weights 208 (see Figure 7), represented by the "W" of the interpolation function 186 may be done by any method known in the art. Nevertheless, the reference already cited above contains suitable methods for calculating 188 the weights.

Using 164 a data-domain sampled network 218 (see Figure 9), may include selecting 190 the data-domain dimensions 134 of interest. Selections may be made without regard to what variables 134 or dimension 134 are independent from which other dimensions 134 e.g., 136, 138, etc.). Selecting 190 may involve merely determining which parameters, and which parameters’ influence thereon are desired to be viewed. In general, one may even select some figure of merit having some functional relationship to parameters, and observe the change in the figure merit as one of the values 106 in a data-domain 100.

Determining 192 arbitrary input and output sets is related to selecting 190 the dimensions 134 of interest. In general, input and output have meaning in experiment design. Nevertheless, in an apparatus or method in accordance with the invention, behaviors and relationships need not be controlled, transformed, manipulated, etc. as a requirement for finding a solution. Thus, an individual may actually select arbitrary sets of dimensions 134 to be included in a selection from a data domain 100. Nevertheless,
in order to obtain the maximum information, all dimensions 134 (recall 134 may represent any and all dimensions) may be used and certain dimensions 134 may be selected for observation as output sets. Likewise, certain dimensions 134 may be put into an input set, and plotted or evaluated at some regular increment for purposes of clearer observation of an output set.

Thereafter, selecting 194 an input point in the data domain 100 is a repetitive process. Selecting 194 any input point in the data domain 100 provides a point in the data-domain at which a value 106 of an interpolation function 186 may provide a corresponding “solution” for the point of interest.

Interpolating 196 an output point, implies calculating an interpolated value 110 corresponding to a point 108 in selected dimensions 102, 104 of a data domain 100. If some equation is available, figure of merit is relied upon, one may find a function value 110 outside of the data domain 100. However, knowledge of functional relationships between the data domain 100 and the other parameters is not required. In general, all inputs and outputs of interest may be considered to be part (dimensions) of the data-domain. Thus, typically, all values found during the interpolating step 196 are typically within the range limits of the data domain. Likewise, interpolating step 196 finds values of dimensions 134 within the data domain 100.

Referring to Figure 7, executable and operational data in accordance with the invention is illustrated. In general, a computer readable memory device 196 corresponding to a computer 11, may store various data structures 200-214. As a practical matter, a multidimensional sampling module 198 may be responsible to embody sampling theory in order to provide the analysis for data in the data-domain 100 spectrum as discussed with respect to Figure 6.

Thus, the multidimensional data-domain analysis output 202 including the frequencies, cycles, interpolation method selections, and selection of the number of required samples in each dimension, and the like, as determined by sampling theory, may be provided as an output of the multidimensional sampling module 198.

A correlation module 204 may be responsible to use outputs from the multidimensional data-domain analysis 202, as well as the raw data points 200 stored in the memory 196 in order to provide the weights 208 or weight calculations 188.

The data-domain sampled network 206 and, in particular, the weights 208 reflect the information obtained from the raw data points 200 in the data domain 100. The interpolation module 212 relies on the weights 208 of the data-domain sampled network 206, and the data points 200 from the data domain 100, and the interpolation functions 210 in order to provide values of interest 214 from the data domain 100.

The selection of input versus output is an arbitrary choice within the context of the data domain 100, as described. Thus, the input or output values 214 of interest, are from the data domain, but are typically not at values of actual raw data 200, since interpolation
functions 210 provide for all intermediate points in a surface 120, 142 in the data domain 100.

Referring to Figure 8, while still continuing to refer to Figure 7, the data structures 194 in the memory device 196 may be executed in a processor 215, such as the processor 12 in the computer 11. The raw data points 200 are provided 216a or processed 216a (216 is generic, 216a-216h are specific) by the multidimensional sampling module 198 in order to provide the multidimensional data-domain analysis 202, an output 202. Thus, cycle numbers, methods of interpolation, and the number of required samples for optimization may all be provided as part of the multidimensional data-domain analysis 202 or output 202.

A correlation module 204 may be employed, and may use any suitable mechanism for correlating the data points 200. A significant advance of the invention over prior art systems is the fact that the correlation module 204 relies only upon the data 200. The multidimensional data-domain analysis 202 is provided based on the data domain 100 and data 200 only, not on transformations, a priori information, hypothesized or analyzed equations, uncoupled channels, or the like. Thus, up through the processes 216c, 216d of the correlation module 204, of data 200 and the analysis output 202, the data domain has been relied upon exclusively, without transformations into other domains.

The data-domain sampled network 206 comes as a direct result 216e of the correlation module 204. The resulting weights 208 characterize the data-domain sampled network 206. Accordingly, the weights 208 along with the data 200 is provided 216f to the interpolation module 212 along with the interpolation functions 210 provided 216h to the interpolation module 212. The interpolation module 212 executes the interpolation in accordance with interpolation functions 210 provided, relying on the data 200 and the weights 208 provided. The output of the interpolation module 212 is a value 214 of interest, within the data domain 100, for any point 226 (see Figure 9) anywhere in the data domain 100.

Referring to Figure 9, the data domain 100 may be viewed as a complete and continuous space. Due to the interpolation module 212, points 110 or values 110 may be defined continuously anywhere within the domain 100, providing a surface 220. The surface 220 is made up of points 221 (e.g., values 110) defined by vectors 224. In general, one may think of the surface 220 as a solution 220 or dependent surface 220 while considering a sub-domain 222 as an independent space 222.

Accordingly, the vectors 224 correspond to points 221 or values 222 mapped throughout the sub-domain 222 of the data-domain 100. That is, the data-domain 100 includes both the surface 220, and the sub-domain 222. Again, the sub-domain 222 and surface 220 may be thought of as respective, arbitrary input and output (e.g. independent and dependent) selections. The surface 220 is a representation of a parameter of interest in the data domain 100 desired to be observed.
Due to the interpolation function 210 and the weights 208, a point 226 that is not included in the original data points 223, but existing within the data domain 100, has a vector 230, the value 232 of which is a point 232 on the surface 220, provided as an output by the interpolation module 212.
CLAIMS

1. A method comprising:
   providing a data domain;
   providing data points in the data domain;
   analyzing, within the data domain, behaviors of the data points in accordance with a multidimensional sampling theory to determine a sampling distribution to be applied in the data domain; and
   providing a data-domain sampled network based on an output of the analyzing in the data domain.

2. The method of claim 1, further comprising:
   providing a computer readable memory containing operational and executable data structures, the data structures comprising:
   providing a multidimensional sampling module, executable to analyze, within the data domain, the data points to determine a sampling architecture; and providing a correlation module, executable to process the data points and the sampling architecture to correlate the data points and provide a data-domain sampled network reflecting the correlation of the data.

3. The method of claim 2, further comprising providing an interpolation module for interpolating a value in a first dimension of interest in the data domain from a point of interest defined by parameters in other dimensions of the data domain.

4. The method of claim 1, further comprising providing an interpolation function developed using the data points in the data domain.

5. The method of claim 4, further comprising providing an interpolation module for interpolating values in a first dimension, corresponding to values in coupled second and third dimensions.

6. The method of claim 5, wherein the interpolating relies on an optimal interpolation function, determined in accordance with the multidimensional sampling theory and by analysis, in the data domain, of the data points.

7. The method of claim 1, further comprising providing the data-domain sampled network, defined by a set of weights reflecting an analysis of untransformed data represented by the data points in the data domain.
8. The method of claim 1, wherein the data points reflect a value in a first dimension of interest corresponding to coupled second and third dimensions.

9. An article comprising a computer readable memory containing operational and executable data structures, the data structures comprising:
   a multidimensional sampling module, executable to analyze, within the data domain, the data points to determine a sampling architecture;
   a correlation module, executable to process the data points and the sampling architecture to correlate the data points and provide a data-domain sampled network reflecting the correlation of the data; and
   an interpolation module for interpolating a value in a first dimension of interest in the data domain from a point of interest defined by parameters in other dimensions of the data domain.

10. An apparatus comprising:
    a processor,
    a memory device, computer readable and operably connected to the processor for storing operational and executable data structures, the data structures comprising:
    data points stored in a data domain and reflecting values in a first dimension;
    a multidimensional sampling module for analyzing, in the data domain, the data points to provide, for a second and third dimension of the data domain, a sampling number, corresponding to a number of samples of data points in a sub-domain including the second and third dimensions; and
    a correlation module, executable to process, in the data domain, the data points and an output of the multidimensional sampling module to provide a data-domain sampled network reflecting a correlation between the second dimension and a third dimension.
Fig. 2
Fig. 5
Provide Data

[Define Independent Variable Domain]
[Define Function Range]

Select Dimensions (Variables, etc...)

Provide Points in Data-Domain
Space/Sub-Space

Analyze Data in Data-Domain Spectrum

Select Dimension
Determine Cycles Per Dynamic Range
[Select Interpolation Method]
Select Number of Sample Points in Dimension

Provide Data-Domain Network

Select Interpolation Function

Apply Sampling Theory to Native Data Domain

Calculate Weights

Select Data Domain Dimensions of Interest

Determine Arbitrary Input/Output Sets

Select Input Point in Data-Domain

Interpolate Output Point [In Data-Domain]

Fig. 6

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Fig. 7

Memory

Raw Data Points in Data Domain

Multi Dimensional Sampling Module

Multi Dimensional Data-Domain Analysis (Cycles/Method/Sample No.)

Correlation Module

Data-Domain Sampled Network

Weights

Interpolation Functions

Interpolation Module

I/O Values of Interest From Data-Domain
Processor

Raw Data Points in Data Domain

Multi Dimensional Sampling Module

Multi Dimensional Data-Domain Analysis (Cycles/Method/Sample No.)

Correlation Module

Data-Domain Sampled Network

Weights

Interpolation Functions

Interpolation Module

I/O Values of Interest From Data-Domain

Fig. 8

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**INTERNATIONAL SEARCH REPORT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>DZIELINSKI, A. ET AL, Multidimensional sampling aspects of neurocontrol with feedforward networks, Artificial Neural Networks, 1995., Fourth International Conference on , 1995, Page(s): 240-244</td>
<td>1-10</td>
</tr>
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<td>A</td>
<td>DZIELINSKI, A. An Algorithm For Nonlinear Systems Modelling Based On N-D Function Reconstruction, Multi-Dimensional Systems: Problems and Solutions, IEE Colloquium on, Jan. 10 1996, Page(s): 12/1</td>
<td>1-10</td>
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[X] Further documents are listed in the continuation of Box C.  
See patent family annex.

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