(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 222 614 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
25.10.2006 Bulletin 2006/43

(21) Application number: **00908627.3**

(22) Date of filing: **11.02.2000**

(51) Int Cl.:
G06K 9/40 *(2006.01)* ***G06T 5/00*** *(2006.01)*
H04N 5/21 *(2006.01)* ***H04N 5/235*** *(2006.01)*
G06T 5/20 *(2006.01)* ***H04N 7/26*** *(2006.01)*
H04N 7/36 *(2006.01)* ***H04N 7/68*** *(2006.01)*

(86) International application number:
PCT/US2000/003739

(87) International publication number:
WO 2000/048118 (17.08.2000 Gazette 2000/33)

(54) **METHOD AND APPARATUS FOR ADAPTIVE CLASS TAP SELECTION ACCORDING TO MULTIPLE CLASSIFICATION**

VERFAHREN UND GERÄT ZUR LERNFÄHIGEN KLASSENAUSWAHL NACH MEHREREN KLASSIFIKATIONEN

PROCEDE ET APPAREIL PERMETTANT DE CHOISIR DES VALEURS DE CLASSE DE FACON ADAPTATIVE EN FONCTION D'UNE CLASSIFICATION MULTIPLE

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **12.02.1999 US 249735**

(43) Date of publication of application:
17.07.2002 Bulletin 2002/29

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Description

[0001] This invention relates generally to the processing of image, sound or other correlated signals, and more particularly, to a method, apparatus, and article of manufacture for restoring a deteriorated signal to an undeteriorated signal.

[0002] Conventionally, to restore an image that is deteriorated in image quality it is necessary to analyze the cause of the deterioration, determine a deterioration model function, and apply its inverse function to the deteriorated image. Various causes of deteriorations are possible, such as a uniform movement of a camera (imaging device such as a video camera) and blurring caused by the optical system of a camera. Therefore, in restoring an image, different model functions may be used for respective causes of deteriorations. Unless the cause of deterioration is found, it is difficult to restore a deteriorated image because a model function cannot be determined.

[0003] In addition, it is frequently the case that even if a model function of a deterioration is established, there is no inverse function for restoration that corresponds to the model function. In such a case, it is difficult to perform evaluation for determining the optimum model.

[0004] Conventionally, error recovery has been achieved by correlation evaluation. For example, some recovery choices have been implemented using a conventional error pixel recovery method. FIG. 1A shows a conventional error recovery block diagram. Using neighboring data, which are shown in FIG. **1B,** spatial inclinations of the target data are detected. In this example, the inclinations regarding four directions are evaluated according to the formulae which are shown in FIG. 1C. An interpolation filter is chosen where the inclination value, E_j, is the smallest among four values. In addition to the spatial inclination, a motion factor is also evaluated for error recovery. In the case of the motion area, a selected spatial filter is used for error recovery. On the other hand, the previous frame data at the same location as the target data are used for error recovery. This evaluation is performed in the evaluation block of FIG. **1A.**

[0005] The conventional error recovery process shown in FiGs. **1A-1C** may cause many serious degradations on changing data, especially on object edges. Actual signal distribution typically varies widely, so these problems are likely to occur. Therefore, there is a need for a way to restore a deteriorated signal to an undeteriorated signal which minimizes degradations on changing data.

[0006] United States Patent No US-A-5 479 211 discloses an image signal decoding apparatus which employs filtering to correct data distortion caused by the inherent lossy quality of the quantized data (as opposed to filtering for error recovery of deteriorated signal points). To this end, respective blocks of the data are examined by circuits that judge maximum frequency in the horizontal and vertical directions and, in response thereto, select horizontal and vertical filters based upon an area containing a pixel by selecting filter size and coefficient.

[0007] United States Patent No US-A-5 790 195 discloses an image signal encoding apparatus in which a prefilter circuit that effects space filtering of input data before it is supplied to the apparatus proper is controlled in response to a prefilter coefficient determined by circuits that detect activity and motion in the input data.

[0008] United States Patent No US-A-5 852 470 discloses apparatus for converting a first (low resolution) video signal into a second (high resolution) video signal by interpolating the first video signal. The apparatus comprises a two-dimensional filter in which a spatial activity code is produced by evaluating the activity of the first video signal, one of a set of pixel patterns is selected based on the spatial activity code and the first video signal is classified using the selected pattern in order to generate a class code, and the second video signal is predictively calculated using one of a plurality of prediction coefficients selected in accordance with the class code.

[0009] The present invention provides a method, article of manufacture and apparatus, as set forth in claims 1, 19 and 37 hereof, respectively, for restoring a deteriorated signal to an undeteriorated signal.

[0010] A preferred form of implementation of the invention is described in detail below with reference to the accompanying drawings. By way of summary thereof, it is to be noted that the preferred implementation processes a deteriorated signal that consists of a plurality of deteriorated and undeteriorated data points. For each deteriorated data point, a plurality of classes is created based upon characteristics of the area containing the deteriorated data point. The data point is classified with respect to the plurality of classes and assigned corresponding input signal classes. The undeteriorated signal is generated by adaptive filtering of the input signal in accordance with the input signal classification results. More than one classification method is used to create the plurality of classes. Created classes may include a motion class, an error class, a spatial class or a spatial activity class. An adaptive class tap structure is used to create the plurality of classes. An adaptive filter tap structure may optionally be used, based on the corresponding plurality of classes. Filter tap expansion may optionally be used to reduce the number of filter coefficients. The deteriorated input signal may optionally be modified by preprocessing peripheral erroneous data. A spatial class may optionally be modified according to spatial symmetry.

[0011] The present invention is illustrated by way of example and may be better understood by referring to the following description in conjunction with the accompanying drawings, in which like references indicate similar elements and in which:

FIGs. IA-IC show a conventional error recovery method, filter tap, and correspondence between inclination value and interpolation filter;

FIGs. 2A-2D show a classified adaptive error recovery method and class compatible with an embodiment of the present invention;
FIG. 3 shows a motion class tap compatible with an embodiment of the present invention;
FIG. 4 shows an error class tap compatible with an embodiment of the present invention;
FIG. **5** shows an adaptive spatial class tap compatible with an embodiment of the present invention;
FIG. **6** shows an adaptive spatial class tap (error class **0**) compatible with an embodiment of the present invention;
FIG. **7** shows an adaptive spatial class tap (error class **1**) compatible with an embodiment of the present invention;
FIG. **8** shows an adaptive spatial class tap (error class **2**) compatible with an embodiment of the present invention;
FIG. **9** shows an adaptive spatial class tap (error class **3**) compatible with an embodiment of the present invention;
FIG. **10** shows an adaptive filter tap compatible with an embodiment of the present invention;
FIG. **11** shows a motion class adaptive filter tap compatible with an embodiment of the present invention;
FIG. **12** shows a motion class adaptive filter tap (error class 0) compatible with an embodiment of the present invention;
FIG. **13** shows a motion class adaptive filter tap (error class **1**) compatible with an embodiment of the present invention;
FIG. **14** shows a motion class adaptive filter tap (error class **2**) compatible with an embodiment of the present invention;
FIG. **15** shows a motion class adaptive filter tap (error class **3**) compatible with an embodiment of the present invention;
FIG. **16** shows a preprocessing algorithm compatible with an embodiment of the present invention;
FIG. **17** shows a motion tap and stationary tap preprocessing algorithm compatible with an embodiment of the present invention;
FIG. **18** shows a system block diagram compatible with an embodiment of the present invention;
FIG. **19** shows coefficient memory contents compatible with an embodiment of the present invention;
FIG. **20** shows an ADRC class reduction based on a 4-tap 1-bit ADRC compatible with an embodiment of the present invention; and
FIG. **21** shows an example of audio signal adaptive classification compatible with an embodiment of the present invention.

[0012] In the following description of an embodiment of the present invention, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration a specific embodiment in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

[0013] The present invention provides a method, apparatus, and article of manufacture for restoring a deteriorated signal to an undeteriorated signal using classified adaptive error recovery. Target data is the particular data of the deteriorated signal whose value is to be determined or estimated.

[0014] Classified adaptive error recovery is the technology which utilizes classified adaptive filter processing. A proper classification with respect to the deteriorated input signal is performed according to the input signal characteristics. An adaptive Filter is prepared for each class prior to error recovery processing.

[0015] More than one classification method may optionally be used to generate the plurality of classes. Generated classes may include a motion class, an error class, a spatial activity class or a spatial class. An adaptive class tap structure may optionally be used to generate the plurality of classes. An adaptive filter tap structure may optionally be used according to the class which is detected in each deteriorated input signal. The adaptive filter tap structure may optionally be expanded based upon multiple taps. The number of filter coefficients that must be stored can be reduced by allocating the same coefficient to multiple taps. This process is referred to as filter tap expansion. The deteriorated input signal may optionally be modified by preprocessing peripheral erroneous data. A spatial class may optionally be eliminated according to a spatial class elimination formula.

[0016] The present invention can be applied to any form of correlated data, including without limitation photographs or other two-dimensional static images, holograms, or other three-dimensional static images, video or other two-dimensional moving images, three-dimensional moving images, a monaural sound stream, or sound separated into a number of spatially related streams, such as stereo. In the description, the term value, in one embodiment, may refer to a component within a set of received or generated data. Furthermore, a data point is a position, place, instance, location or range within data.

[0017] For the sake of clarity, some of the description herein focuses on video data comprising a pixel stream. However, it will be recognized that the present invention may be used with other types of data other than video data and that the terms and phrases used herein to describe the present invention cover a broad range of applications and data types. For example, an adaptive class tap structure is an adaptive structure for class tap definition used in multiple classification. A spatial class, a motion class and an error class may be used to define the structure. An adaptive filter tap structure is an adaptive structure for filter tap definition based upon a corresponding class.

[0018] A class may be defined based on one or more characteristics of the target data. For example, a class may also be defined based on one or more characteristics of the group containing the target data. A class ID is a specific value within the class that is used to describe and differentiate the target data from other data with respect to a particular

characteristic. A class ID may be represented by a number, a symbol, or a code within a defined range. A parameter may be used as a predetermined or variable quantity that is used in evaluating, estimating, or classifying the data. For example, the particular motion class ID of a target data can be determined by comparing the level of motion quantity in the block containing the target data against a parameter which can be a pre-determined threshold.

Multiple Classification

[0019] In one embodiment, a multiple class may be used as a collection of specific values or sets of values used to describe at least two different characteristics of the target data. For example, a multiple class may be defined to be a combination of at least two different classes. For example, a multiple class may be defined to be a combination of an error class, a motion class, and a spatial class such as an ADRC class.

[0020] In one embodiment, the multiple class ID can be used as the memory address to locate the proper filter coefficients and other information that are used to determine or estimate the value of the target data. In one embodiment, a simple concatenation of different class IDs in the multiple class ID is used as the memory address.

[0021] Therefore, a multiple classification scheme is a way of classifying the target data with respect to more than one characteristic of the target data in order to more accurately determine or estimate the value of the target data.

[0022] An error class is a collection of specific values used to describe the various distribution patterns of erroneous data in the neighborhood of the target data. In one embodiment, an error class is defined to indicate which adjacent data to the target data is erroneous. An error class ID is a specific value within the error class used to describe a particular distribution pattern of erroneous data in the neighborhood of the target data. For example, an error class ID of "0" may be defined to indicate that there is no erroneous data to the left and to the right of the target data; an error class ID of "1" may be defined to indicate that the data to the left of the target data is erroneous, etc. A filter is a mathematical process, function or mask for selecting a group of data.

[0023] A motion class is a collection of specific values used to describe the motion characteristic of the target data. In one embodiment, the motion class is defined based on the different levels of motion of the block containing the target data, for example; no motion in the block, little motion in the block, or large motion in the block. A motion class ID is a specific value within the motion class used to indicate a particular level of motion quantity of the target data. For example, motion class ID of "0" may be defined to indicate no motion, motion class ID of "3" may be defined to indicate large motion.

[0024] A spatial class is.a collection of specific values used to describe the spatial characteristic of the target data. For example, spatial classification of the data may be determined using Adaptive Dynamic Range Coding (ADRC), Differential Pulse Code Modulation (DPCM), Vector Quantization (VQ), Discrete Cosine Transform (DCT), etc. A spatial class ID is a specific value within the spatial class used to describe the spatial pattern of the target data in the group or block containing the target data.

[0025] For example, an ADRC class is a spatial class defined by the Adaptive Dynamic Range Coding method. An ADRC class ID is a specific value within the ADRC class used to describe the spatial pattern of the data distribution in the group or block containing the target data. A class is a collection of specific values used to describe certain characteristics of the target data. A variety of different types of classes exist, for example, a motion class, a spatial class, an error class, a spatial activity class, etc.

[0026] The present invention provides a method and apparatus for adaptive processing that generates data corresponding to a set of one or more data classes. This process is known as "classification". Classification can be achieved by various attributes of signal distribution. For example, Adaptive Dynamic Range Coding (ADRC) may be used for generation of each class as a spatial class, but it will be recognized by one of ordinary skill in the art that other classes, including a motion class, an error class, and a spatial activity class may be used with the present invention without loss of generality. A spatial activity class is a collection of specific values used to describe the spatial activity characteristic of the target data. For example, spatial activity classification of the data may be determined using the dynamic range, the standard deviation, the Laplacian value or the spatial gradient value. Some classification methods provide advantages which are desirable before restoration of a deteriorated signal takes place. For example, ADRC can achieve classification by normalizing each signal waveform automatically.

[0027] For each class, a suitable filter for signal restoration is prepared for the adaptive processing. In one embodiment, each filter is represented by a matrix of filter coefficients which are applied to the data. The filter coefficients can be generated by a training process, an example of which is described subsequently, that occurs as a preparation process prior to filtering. In one embodiment of the present invention, the filter coefficients can be stored in a random access memory (RAM), shown in FIG. **2A** at **207.**

[0028] A typical signal processing flow of the present invention is shown in FIG. **2A.** Target input data **201** can be accompanied with error flag data **203.** Error flag data can indicate locations within the data that contain erroneous pixels. In one embodiment of the present invention, an ADRC class is generated for each input target data in classification block **205**, filter coefficients corresponding to each class ID are output from the coefficient memory block **207**, and filtering is executed with input data **201** and the filter coefficients in the filter block **209.** The filtered data may correspond to an

error recovered result. In the selector block **211**, switching between error recovered data and error free data occurs according to the error flag data **203.**

[0029] In FIG. **2B**, an example is shown where the number of class taps is four. In the case of 1-bit ADRC, **16** class IDs are available as given by [formula **3**], shown below. ADRC is realized by [formula **2**], shown below. Detecting a local dynamic range (DR) is given by [formula **1**], shown below,

$$DR = MAX - MIN + 1 \qquad \text{[formula 1]}$$

$$q_i = \left\lfloor \frac{(x_i - MIN + 0.5) \cdot 2^Q}{DR} \right\rfloor \qquad \text{[formula 2]}$$

$$c = \sum_{i=1}^{4} 2^{i-1} \cdot q_i \qquad \text{[formula 3]}$$

where c corresponds to an ADRC class ID, DR represents the dynamic range of the four data area, *MAX* represents the maximum level of the four data, *MIN* represents the minimum level of the four data, *qi* is the ADRC encoded data, also referred to as a Q code, and Q is the number of quantization bits. The $\lfloor \cdot \rfloor$ operator represents a truncation operation.

[0030] In **1**-bit ADRC, c may have a value from **0** to **15** with Q = **1**. This process is one type of spatial classification, but it will be recognized by one of ordinary skill in the art that other examples of spatial classification, including Differential PCM, Vector Quantization and Discrete Cosine Transform may be used with the present invention without loss of generality. Any method may be used if it can classify a target data distribution.

[0031] In the example shown in FIG. **2C**, each adaptive filter has **12** taps. Output data is generated according to the linear combination operation given by [formula **4**], shown below,

$$y = \sum_{i=1}^{12} w_i \cdot x_i \qquad \text{[formula 4]}$$

where x_i is input data, w_i corresponds to each filter coefficient, and y is the output data after error recovery. Filter coefficients can be generated for each class ID by a training process that occurs prior to the error recovery process.

[0032] For example, training may be achieved according to the following criterion.

$$\min_{w} \left\| X \cdot W - Y \right\|_2 \qquad \text{[formula 5]}$$

where *X, W,* and *Y* are, for example, the following matrices: X is the input data matrix defined by [formula **6**], *W* is the coefficient matrix defined by [formula **7**], and *Y* corresponds to the target data matrix defined by [formula **8**].

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \quad \text{[formula 6]}$$

$$W = \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} \quad \text{[formula 7]}$$

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{pmatrix} \quad \text{[formula 8]}$$

[0033] The coefficient w_i can be obtained according to [formula 5], so that estimation errors against target data are minimized.

[0034] In the example shown in FIG. **2C, 12** coefficients regarding each ADRC class ID are determined by the training method described above.

[0035] A flow diagram of an embodiment of the present invention is shown in FIG. **2D.** The flow chart of FIG. **2D** shows the basic processing stream for generating an undeteriorated signal from the deteriorated input signal. At step **215,** the preprocessing for a peripheral erroneous pixel is performed. At step **217,** each classification regarding the deteriorated input signal is executed to generate a class ID. Some class taps are selected adaptively according to another class ID. Multiple classification may be executed, such as motion classification, error classification, spatial activity classification and spatial classification.

[0036] The classification scheme can be defined during system design, where the classification scheme, the number of classes, and other specification are decided for the target data. The design stage may include, among others, considerations of system performance and hardware complexity.

[0037] At step **219,** multiple classification generates a multiple class ID with a plurality of class IDs which are generated by various classification at step **217.** At step **221,** filter taps are adaptively selected according to the multiple class ID which is generated at step **219.** At step **223,** the filter tap structure is adaptively expanded according to the multiple class ID which is generated at step **219.** The number of filter coefficients that must be stored can be reduced by allocating the same coefficient to multiple taps. This process is referred to as filter tap expansion. At step **224,** filter coefficients are selected according to the multiple class ID which is generated at step **219.** At step **225,** filtering with respect to the deteriorated input signal is executed to generate an undeteriorated signal. Filter coefficients are selected adaptively according to the multiple class ID which is generated in step **219.**

[0038] In one embodiment of the present invention, a three dimensional ADRC process may be used to realize spatio-temporal classification, because simple waveform classifications such as a two dimensional ADRC process typically cannot structurally achieve separation for general motion pictures in the class of FIG. 2B. If both stationary and motion areas are processed in the same class ID, error recovery quality is degraded because of differences in characteristics of the two areas.

[0039] In another embodiment of the present invention, motion classification, in addition to spatial classification, may

also be used to provide compact definition of temporal characteristics. Further, multiple classification may be added to the classified adaptive error recovery method. For example, there are various types of classes, such as a motion class, an error class, a spatial activity class and a spatial class explained above. The combination of one or more of these different classification methods can also improve classification quality.

[0040] FIG. **3** shows an example of motion class tap structures. The example shows eight taps in neighborhood of the target error data. In this example, the eight tap accumulated temporal difference can be evaluated according to [formula **9**], shown below, and is classified to four kinds of motion classes by thresholding based on [formula **10**], shown below. In one embodiment of the present invention, th**0** is equal to **3**, th**1** is equal to **8**, and th**2** is equal to **24.**

$$fd = \sum_{i=1}^{8} |x_i - x'_i| \qquad \text{[formula 9]}$$

$$mc = \begin{cases} 0 & (0 \leq fd < th0) \\ 1 & (th0 \leq fd < th1) \\ 2 & (th1 \leq fd < th2) \\ 3 & (th2 \leq fd) \end{cases} \qquad \text{[formula 10]}$$

[0041] In the above formulas, *fd* represents an accumulated temporal difference, x_i represents motion class tap data of the current frame, x'_i represents the previous frame tap data corresponding to the current frame, and *mc* represents a motion class ID. Three thresholds, th**0**, th**1**, th**2**, can be used for this motion classification.

[0042] In one embodiment of the present invention, an error class can be used in conjunction with the classified adaptive error recovery method. This classification is achieved according to the erroneous data distribution pattern in neighborhood of the target data, examples of which are shown in FIG. **4.** This example has four error classes: an independent error case, a left error case, a right error case, and a three consecutive error case.

[0043] Generally speaking, filter coefficients of pixels adjacent to the target data have larger weights for error recovery. The data adjacent to the error data has a significant impact on the result of error recovery. Error classes can reduce this influence by separating different characteristic areas to other classes according to the adjacent erroneous data distribution. For the example shown in FIG. 2B, ADRC classification generates 16 kinds of ADRC class IDs, where motion and error classification generate four kinds of class IDs, respectively. Thus, the number of class IDs equals **16x4x4**, or 256. Classification may be realized by representing each signal characteristic. Multiple classification can define a suitable class, the class ID, regarding the erroneous target data by combining different classification characteristics.

Adaptive Class Tap Structure

[0044] In one embodiment of the present invention, an adaptive class tap structure can be used in conjunction with the classified adaptive error recovery method. FIG. **5** shows one example of motion class adaptive spatial class tap structures. Intra-frame taps can be chosen in a stationary or a slow motion area. Intra-field taps are typically used for larger motion areas. Suitable spatial classification is achieved by this adaptive processing.

[0045] For example, if intra-frame taps are used for large motion area classification, then the generated class distribution may vary widely because of low correlation, and therefore it will be difficult to represent the target data characteristics properly. An adaptive class tap structure, such as that shown in FIG. **5**, is therefore effective.

[0046] Additional examples are shown in FIGs. **6, 7, 8, 9.** Spatial class taps are typically selected according to a motion and an error class. In addition to the motion factor, the erroneous data distribution is taken into account for the spatial class tap definition. The neighboring erroneous data is typically not introduced to the spatial classification. By this definition, only valid data is used and the classification accuracy is improved.

Adaptive Filter Tap Structure

[0047] In one embodiment of the present invention, an adaptive filter tap structure based on a corresponding class can be used in conjunction with the classified adaptive error recovery method. FIG. **10** shows one example of an adaptive filter tap structures based on an error class. The filter tap structure regarding the target data is typically defined adaptively,

preferably avoiding damaged data in neighborhood. Damaged data is not chosen for filtering.

[0048] An adaptive filter tap structure can be also defined according to motion class, an example of which is shown in FIG. **11.** In the motion class example shown in FIG. **10**, motion class **0** corresponds to stationary areas, but motion class 3 corresponds to large motion areas. Motion classes **1** and **2** correspond to intermediate motion areas.

[0049] For stationary or quasi-stationary class areas, intra-frame taps are used as shown in FIG. **11.** At the same time, previous frame data at the target data location may be used for error recovery filtering. These areas correspond to motion class **0** and **1.** For fast motion or moderate motion areas, each filter typically has an intra-field taps structure, which is also shown in FIG. **11.** As shown by the example in FIG. **11**, previous frame data is not introduced, and thus weakly correlated data is ignored. Filtering quality is typically improved by intra-field taps in such cases.

[0050] FIG. **12** shows an example of motion and error class adaptive filter tap structures. FIGs. **10** and **11** represent error and motion class adaptive filter taps, respectively. The example shown in FIG. **12** illustrates both adaptive structures with error class**0**, which is the independent error case. Upper adaptive characteristics are also shown in this example. In a manner similar to that of FIG. **12**, FIG. **13** corresponds to error class **1**, FIG. **14** corresponds to error class **2** and FIG. **15** corresponds to error class **3.**

Filter Tap Expansion

[0051] In one embodiment of the present invention, filter tap expansion by allocating the same coefficient to plural taps can be used in conjunction with the classified adaptive error recovery method. Filter tap expansion is also shown by the structures in FIGs. **12-15.** For example, the filter tap structure has four of the same coefficient taps with motion class **3** in FIG. **12.** According to the evaluation results, some tap coefficients can be replaced with the same coefficient. The example shown in FIG. **12** has four W3 coefficients that are allocated at horizontally and vertically symmetric locations. By this expansion, **14** coefficients can cover **18** tap areas. This reduction method can typically reduce the need for coefficient memory and filtering hardware such as adders and multipliers. In one embodiment of the present invention, the expansion tap definition may be achieved by evaluation of coefficient distribution and visual results.

Preprocessing For Peripheral Erroneous Data

[0052] In one embodiment of the present invention, preprocessing for peripheral erroneous data can be used in conjunction with the classified adaptive error recovery method. To achieve error recovery filtering, suitable data is necessary at peripheral error locations of filter taps.

[0053] One example of this preprocessing is shown by the flow diagram of FIG. **16.** If at steps **1601**, **1605**, or **1609** there is erroneous data at a peripheral location of the target data, at steps **1603**, **1607**, **1611** the erroneous data is replaced with horizontal processed data in the case of no horizontal errors. If at steps **1613**, **1617**, or **1621** there are three consecutive horizontal errors, at steps **1615**, **1619**, or **1623** vertical processing is applied for generating preprocessed data. In all erroneous cases around the intra-frame data of this example, previous frame data is introduced for error processing, at step 1625.

[0054] FIG. **17** shows another preprocessing example that uses a motion adaptive process for preprocessing. Using error free data, motion quantity is detected at the motion detection step **1701.** Generally speaking, an averaged motion quantity is calculated by averaging summed motion quantity with the number of error free data at the next step. Motion or stationary taps are chosen at step **1703** according to a threshold value of the result of averaged motion quantity. After these steps, processing steps **1705** through **1729** are performed in a manner similar to steps **1601** through **1625** of FIG. **16.** The preprocessed data is generated according to these prioritized processes, and is introduced for error recovery filtering.

Spatial Class Reduction

[0055] In one embodiment of the present invention, spatial class reduction can be used in conjunction with the classified adaptive error recovery. As explained above, an ADRC class can be used for the spatial classification, given by [formula **3**]. This has **16** kinds of class IDs in the definition of a **4** tap ADRC. These **16** class IDs can be reduced to eight kinds of class IDs according to [formula **11**], shown below,

$$c = \begin{cases} \sum_{i=1}^{4} 2^{i-1} \cdot q_i & (c < 2^3) \\ 2^4 - 1 - \sum_{i=1}^{4} 2^{i-1} \cdot q_i & (c \geq 2^3) \end{cases} \qquad \text{[formula 11]}$$

where c corresponds to the ADRC class ID, q_i is the quantized data and Q is the number of quantization bits based on [formula **1**] and [formula **2**].

[0056] In one embodiment of the present invention, [formula **11**] corresponds to a 1's complement operation in binary data of the ADRC code. This is related to the symmetric characteristics of each signal waveform. Because ADRC classification is a normalization of the target signal waveform, two waveforms which have the relation of 1's complement in each ADRC code can be classified in the same class ID. ADRC class IDs can typically be halved by this reduction process. An ADRC class reduction based on a 4-tap 1-bit ADRC is shown in FIG. **20.** In this example, applying [formula **11**] gives eight ADRC class pairs. Each pair contains spatial symmetric patterns, and therefore the number of ADRC class IDs can be reduced by half by taking advantage of these symmetric patterns. The spatial class reduction technique can also be applied to other spatial classification techniques, including but not limited to DPCM and Block Truncation Coding (BTC).

System Structure

[0057] An overall system structure for one embodiment of the present invention, including all the processes described above, is shown in FIG. **18.** Input data **1801** and corresponding error flags **1803** are input to the system. Examining the error flags **1803,** the input data **1801** is preprocessed at **1805.** ADRC classification is performed at **1807,** motion classification is performed at **1809,** and error classification is performed at **1811.**

[0058] In this example, ADRC class taps are chosen adaptively according to the error and motion class, such as shown in FIGs. **6, 7, 8, 9.** Filter tap data are chosen at **1813** based on the error and motion class, such as shown in FIGs. **12, 13, 14, 15.** Error recovery filtering is performed at **1817** with tap data and filter coefficients selected from the coefficient memory **1815** corresponding to the ADRC class ID of **1807,** the motion class ID of **1809** and the error class ID of **1811.** Error recovered data and error free input data **1817** are selected at **1821** according to the error flag **1803,** which produces the output data **1823** of this system.

[0059] FIG. **19** shows an example of coefficient memory contents. It has **4x4x8** or **128** class IDs according to the multiple classification scheme. Four categories are used for an error class, four categories are for a motion class, and eight categories are for an ADRC class, which are typically halved according to [formula **11**]. Each class corresponds to each memory address in FIG. **19.** In this example, **14** coefficients are stored in each class ID address according to the filter definition, like FIGs. **12, 13, 14, 15.**

[0060] The present invention may be used with any form of correlated data, including without limitation photographs or other two-dimensional static images, holograms, or other three-dimensional static images, video or other two-dimensional moving images, three-dimensional moving images, a monaural sound stream, or sound separated into a number of spatially related streams, such as stereo. FIG. **21** shows an example of audio signal adaptive classification compatible with the present invention. An example audio signal **2101** is monitored at one or more time points **t0 - t8.** The level of the audio signal **2101** at time points **t0 -t8** is given by tap points **X0** - X**8**. The dynamic range of the audio signal **2101** is given as the difference between the lowest level tap point **X0** and the highest level tap point X**4**. In case of error recovery for erroneous data at t**4**, multiple classification can be applied with spatial classification like ADRC classification and spatial activity classification like dynamic range classification. Dynamic range classification is performed by thresholding the dynamic range in a manner similar to the motion classification processing of [formula **10**]. As described above, motion classification, error classification and spatial classification are referred to in multiple classification. Spatial activity classification can also be introduced to multiple classification for general applications such as video data. In addition to dynamic range, the standard deviation, the Laplacian value or the spatial gradient value can be introduced for spatial activity classification.

[0061] With the present invention, the quality of data that is recovered due to errors is improved by introducing the disclosed technologies to the classified adaptive error recovery method. The present invention provides a way to restore a deteriorated signal to an undeteriorated signal which minimizes degradations on changing data.

[0062] While the invention is described in terms of embodiments in a specific system environment, those of ordinary skill in the art will recognize that the invention can be practiced, with modification, in other and different hardware and

software environments within the scope of the appended claims.

Claims

1. A method for restoring a deteriorated input signal (201) comprising the steps of:

   detecting a deteriorated data point of the deteriorated input signal;
   using an adaptive class tap structure and more than one classification method to create a plurality of classes based upon characteristics of an area containing the data point;
   classifying the area containing the data point with respect to the plurality of classes (217);
   creating a multiple classification result from the classes under which the area is classified (219), the multiple classification result having an identifier;
   selecting a filter corresponding to the multiple classification result using the identifier (224), the filter comprising filter coefficients;
   creating an undeteriorated data point by filtering the area with the filter corresponding to the multiple classification result (225); and
   outputting an undeteriorated signal (213) corresponding to the input signal (201).

2. The method of claim 1 wherein the step of creating a multiple classification result (219) comprises creating the multiple classification result based upon a plurality of class IDs with the plurality of classes.

3. The method of claim 1 further comprising the step of adaptively selecting class taps for the plurality of classifications according to a class ID (221).

4. The method of claim 1 further comprising the step of adaptively selecting class taps for the plurality of classifications according to a motion class (1809).

5. The method of claim 1 further comprising the step of adaptively selecting class taps for the plurality of classifications according to an error class (1811).

6. The method of claim 1 further comprising the step of adaptively selecting class taps for the plurality of classifications according to a motion class and an error class (1813).

7. The method of claim **1** further comprising the step of creating a spatial class (1807).

8. The method of claim **1** further comprising the step of creating an Adaptive Dynamic Range Coding (ADRC) class (1807).

9. The method of claim **1** further comprising the step of creating a Differential Pulse Code Modulation (DPCM) class.

10. The method of claim **1** further comprising the step of creating a Vector Quantization (VQ) class.

11. The method of claim **1** further comprising the step of creating a Discrete Cosine Transform (DCT) class.

12. The method of claim **1** further comprising the step of creating a motion class (1809).

13. The method of claim **1** further comprising the step of creating an error class (1811).

14. The method of claim **1** further comprising the step of creating a spatial activity class.

15. The method of claim **1** further comprising the step of creating a dynamic range class.

16. The method of claim **1** further comprising the step of creating a standard deviation class.

17. The method of claim **1** further comprising the step of creating a Laplacian class.

18. The method of claim 1 further comprising the step of creating a spatial gradient class.

19. An article of manufacture for use in a computer system to restore a deteriorated input signal (201), the article of manufacture comprising a computer usable medium having computer readable program code means embodied in the medium, the program code means including:

computer readable program code means embodied in the computer usable medium for causing a computer to detect a deteriorated data point of the deteriorated input signal;
computer readable program code means embodied in the computer usable medium for causing a computer to use an adaptive class tap structure and more than one classification method to create a plurality of classes based upon characteristics of an area containing the data point;
computer readable program code means embodied in the computer usable medium for causing a computer to classify the area containing the data point with respect to the plurality of classes (217);
computer readable program code means embodied in the computer usable medium for causing a computer to create a multiple classification result from the classes under which the area is classified (219), the multiple classification result having an identifier;
computer readable program code means embodied in the computer usable medium for causing a computer to select a filter corresponding to the multiple classification result using the identifier (224), the filter comprising filter coefficients;
computer readable program code means embodied in the computer usable medium for causing a computer to create an undeteriorated data point by filtering the area with the filter corresponding to the multiple classification result (225); and
computer readable program code means embodied in the computer usable medium for causing a computer to output an undeteriorated signal (213) corresponding to the input signal (201).

20. The article of manufacture of claim 19 further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create the multiple classification result based upon a plurality of class IDs with the plurality of classes (219).

21. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to adaptively select class taps for the plurality of classifications according to a class ID (221).

22. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to adaptively select class taps for the plurality of classifications according to a motion class (1809).

23. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to adaptively select class taps for the plurality of classifications according to an error class (1811).

24. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to adaptively select class taps for the plurality of classifications according to a motion class and an error class (1813).

25. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a spatial class (1807).

26. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create an Adaptive Dynamic Range Coding (ADRC) class (1807).

27. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a Differential Pulse Code Modulation (DPCM) class.

28. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a Vector Quantization (VQ) class.

29. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a Discrete Cosine Transform (DCT) class.

30. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a motion class (1809).

31. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create an error class (1811).

32. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a spatial activity class.

33. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a dynamic range class.

34. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a standard deviation class.

35. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a Laplacian class.

36. The article of manufacture of claim **19** further comprising computer readable program code means embodied in the computer usable medium for causing a computer to create a spatial gradient class.

37. An apparatus for restoring a deteriorated input signal (1801) comprising:

means for detecting a deteriorated data point of the deteriorated input signal;
means for using an adaptive class tap structure and more than one classification method to create a plurality of classes based upon characteristics of an area containing the data point;
means for classifying (1807, 1809, 1811) the area containing the data point with respect to the plurality of classes;
means for creating a multiple classification result from the classes under which the area is classified, the multiple classification result having an identifier;
means for selecting (1815) a filter corresponding to the multiple classification result, using the identifier, the filter comprising filter coefficients;
means for creating (1817) an undeteriorated data point by filtering the area with the filter corresponding to the multiple classification result; and
means for outputting (1821) an undeteriorated signal (1823) corresponding to the input signal(1801).

38. The apparatus of claim 37 wherein the means for creating the multiple classification result is operative to create the result based upon a plurality of class IDs with the plurality of classes.

39. The apparatus of claim 37 further comprising a second means for selecting (1813) to adaptively select class taps for the plurality of classifications according to a class ID.

40. The apparatus of claim 37 further comprising a second means for selecting (1813) to adaptively select class taps for the plurality of classifications according to a motion class (1809).

41. The apparatus of claim 37 further comprising a second means for selecting (1813) to adaptively select class taps for the plurality of classifications according to an error class (1811).

42. The apparatus of claim 37 further comprising a second means for selecting (1813) to adaptively select class taps for the plurality of classifications according to a motion class and an error class (1809,1811).

43. The apparatus of claim **37** further comprising a class generator to create a spatial class (1807).

44. The apparatus of claim **37** further comprising a class generator to create an Adaptive Dynamic Range Coding (ADRC) class (1807).

45. The apparatus of claim **37** further comprising a class generator to create a Differential Pulse Code Modulation (DPCM) class.

46. The apparatus of claim **37** further comprising a class generator to create a Vector Quantization (VQ) class.

47. The apparatus of claim **37** further comprising a class generator to create a Discrete Cosine Transform (DCT) class.

48. The apparatus of claim **37** further comprising a class generator to create a motion class (1809).

49. The apparatus of claim **37** further comprising a class generator to create an error class (1811).

50. The apparatus of claim **37** further comprising a class generator to create a spatial activity class.

51. The apparatus of claim **37** further comprising a class generator to create a dynamic range class.

52. The apparatus of claim **37** further comprising a class generator to create a standard deviation class.

53. The apparatus of claim **37** further comprising a class generator to create a Laplacian class.

54. The apparatus of claim 37 further comprising a class generator to create a spatial gradient class.

Patentansprüche

1. Verfahren zum Wiederherstellen eines qualitätsverminderten Eingangssignals (201) mit folgenden Schritten:

Detektieren eines qualitätsverminderten Datenpunktes des qualitätsverminderten Eingangssignals;
Verwenden einer Abgriffsstruktur für eine adaptive Klasse und mehr als ein Klassifikationsverfahren, um mehrere Klassen anhand der Eigenschaften eines Bereichs, der den Datenpunkt enthält, zu erzeugen;
Klassifizieren des Bereichs, der den Datenpunkt enthält, mit Bezug zu den mehreren Klassen (217);
Erzeugen eines Mehrfach-Klassifikations-Ergebnisses aus den Klassen, in denen der Bereich klassifiziert ist (219), wobei das Mehrfach-Klassifikations-Ergebnis einen Identifizierer aufweist;
Auswählen eines Filters, der dem Mehrfach-Klassifikations-Ergebnis entspricht, mit Hilfe des Identifizierers (224), wobei der Filter Filterkoeffizienten umfasst;
Erzeugen eines nicht qualitätsverminderten Datenpunktes, indem der Bereich mit dem Filter, der dem Mehrfach-Klassifikations-Ergebnis (225) entspricht, gefiltert wird; und
Ausgeben eines nicht qualitätsverminderten Signals (213), das dem Eingangssignal (201) entspricht.

2. Verfahren nach Anspruch 1, wobei der Schritt des Erzeugens eines Mehrfach-Klassifikations-Ergebnisses (219) das Erzeugen des Mehrfach-Klassifikations-Ergebnisses anhand mehrerer Klassen-IDs aus den mehreren Klassen umfasst.

3. Verfahren nach Anspruch 1, das weiterhin den Schritt des adaptiven Auswählens von Klassenabgriffen für die mehreren Klassifikationen gemäß einer Klassen-ID (221) umfasst.

4. Verfahren nach Anspruch 1, das weiterhin den Schritt des adaptiven Auswählens von Klassenabgriffen für die mehreren Klassifikationen gemäß einer Bewegungs-Klasse (1809) umfasst.

5. Verfahren nach Anspruch 1, das weiterhin den Schritt des adaptiven Auswählens von Klassenabgriffen für die mehreren Klassifikationen gemäß einer Fehler-Klasse (1811) umfasst.

6. Verfahren nach Anspruch 1, das weiterhin den Schritt des adaptiven Auswählens von Klassenabgriffen für die mehreren Klassifikationen gemäß einer Bewegungs-Klasse und einer Fehler-Klasse (1813) umfasst.

7. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer räumlichen Klasse (1807) umfasst.

8. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Adaptiven-Dynamikbereich-Kodierungs-Klasse (Adaptive Dynamic Range Coding (ADRC)) (1807) umfasst.

9. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Differenzielle-Pulscode-Modulations-Klasse (DPCM) umfasst.

10. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Vektorquantisierungs-Klasse (VQ) umfasst.

11. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Diskrete-Kosinustransformations-Klasse (DCT) umfasst.

12. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Bewegungs-Klasse (1809) umfasst.

13. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Fehler-Klasse (1811) umfasst.

14. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Räumliche-Aktivitäts-Klasse umfasst.

15. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Dynamischer-Bereichs-Klasse umfasst.

16. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Standardabweichungs-Klasse umfasst.

17. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Laplace-Klasse umfasst.

18. Verfahren nach Anspruch 1, das weiterhin den Schritt des Erzeugens einer Räumlicher-Gradient-Klasse umfasst.

19. Produkt zur Verwendung in einem Computersystem, um ein qualitätsvermindertes Eingangssignal (201) wiederherzustellen, wobei das Produkt ein computerverwendbares Medium mit einem computerlesbaren Programmcode umfasst, der in dem Medium vorgesehen ist, wobei der Programmcode umfasst:

einen computerlesbaren Programmcode, der in dem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, einen qualitätsverminderten Datenpunkt eines qualitätsverminderten Eingangssignals zu detektieren;
einen computerlesbaren Programmcode, der in dem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Abgriffsstruktur für eine adaptive Klasse und mehr als ein Klassifikationsverfahren zu verwenden, um mehrere Klassen anhand von Eigenschaften eines Bereichs, der den Datenpunkt enthält, zu erzeugen;
einen computerlesbaren Programmcode, der in dem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, um den Bereich, der den Datenpunkt enthält, mit Bezug auf die mehreren Klassen (217) zu klassifizieren;
einen computerlesbaren Programmcode, der in dem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, ein Mehrfach-Klassifikations-Ergebnis aus den Klassen, in denen der Bereich klassifiziert wird (219), zu erzeugen, wobei das Mehrfach-Klassifikations-Ergebnis einen Identifizierer aufweist;
einen computerlesbaren Programmcode, der in dem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, einen Filter, der dem Mehrfach-Klassifikations-Ergebnis entspricht, mit Hilfe des Identifizierers (224) auszuwählen, wobei der Filter Filterkoeffizienten umfasst;
einen computerlesbaren Programmcode, der in dem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, einen nicht qualitätsverminderten Datenpunkt zu erzeugen, indem der Bereich mit dem Filter gefiltert wird, der dem Mehrfach-Klassifikations-Ergebnis (225) entspricht; und
einen computerlesbaren Programmcode, der in dem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, ein nicht qualitätsverminderten Signal (213) auszugeben, das dem Eingangssignal (201) entspricht.

20. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, das Mehrfach-Klassifikations-Ergebnis anhand von mehreren Klassen-IDs mit den mehreren Klassen (219) zu erzeugen.

21. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, die Klassenabgriffe für die mehreren Klassifikationen gemäß einer Klassen-ID (221) adaptiv auszuwählen.

22. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, die Klassenabgriffe für die mehreren Klassifikationen gemäß einer Bewegungs-Klasse (1809) adaptiv auszuwählen.

23. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, die Klassenabgriffe für die mehreren Klassifikationen gemäß einer Fehler-Klasse (1811) adaptiv auszuwählen.

24. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, die Klassenabgriffe für die mehreren Klassifikationen gemäß einer Bewegungs-Klasse und einer Fehler-Klasse (1813) adaptiv auszuwählen.

25. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine räumliche Klasse (1807) zu erzeugen.

26. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Adaptive-Dynamikbereich-Kodierungs-Klasse (ADRC) (1807) zu erzeugen.

27. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Differenzielle-Pulscodemodulations-Klasse (DPCM) zu erzeugen.

28. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Vektorquantisierungs-Klasse (VQ) zu erzeugen.

29. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Diskrete-Kosinustransformations-Klasse (DCT) zu erzeugen.

30. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Bewegungs-Klasse (1809) zu erzeugen.

31. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Fehler-Klasse (1811) zu erzeugen.

32. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Räumliche-Aktivitäts-Klasse zu erzeugen.

33. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Dynamische-Bereichs-Klasse zu erzeugen.

34. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Standardabweichungs-Klasse zu erzeugen.

35. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Lalace-Klasse zu erzeugen.

36. Produkt nach Anspruch 19, das weiterhin einen computerlesbaren Programmcode umfasst, der in einem computerverwendbaren Medium vorgesehen ist, um einen Computer zu veranlassen, eine Räumliche-Gradienten-Klasse zu erzeugen.

37. Vorrichtung zum Wiederherstellen eines qualitätsverminderten Eingangssignals (1801) umfassend:

eine Detektionseinrichtung zum Detektieren eines qualitätsverminderten Datenpunktes des qualitätsverminder-

ten Eingangssignals;
eine Anwendungseinrichtung zum Verwenden einer Abgriffsstruktur für eine adaptive Klasse und mehr als ein Klassifikationsverfahren, um mehrere Klassen anhand der Eigenschaften eines Bereichs, der den Datenpunkt enthält, zu erzeugen;
eine Klassifizierungseinrichtung zum Klassifizieren (1807, 1809, 1811) des Bereichs, der den Datenpunkt enthält, mit Bezug auf die mehreren Klassen;
eine Erzeugungseinrichtung zum Erzeugen eines Mehrfach-Klassifikations-Ergebnisses von den Klassen, in denen der Bereich klassifiziert ist, wobei das Mehrfach-Klassifikations-Ergebnis einen Identifizierer aufweist;
eine Auswahleinrichtung zum Auswählen (1815) eines Filters, der dem Mehrfach-Klassifikations-Ergebnis entspricht, mit Hilfe des Identifizierers, wobei der Filter Filterkoeffizienten aufweist;
eine Erzeugungseinrichtung zum Erzeugen (1817) eines nicht qualitätsverminderten Datenpunktes, indem der Bereich mit dem Filter gefiltert wird, der dem Mehrfach-Klassifikations-Ergebnis entspricht; und
eine Ausgabeeinrichtung zum Ausgeben (1821) eines nicht qualitätsverminderten Signals (1823), der dem Eingangssignal (1801) entspricht.

38. Vorrichtung nach Anspruch 37, wobei die Einrichtung zum Erzeugen des Mehrfach-Klassifikations-Ergebnisses geeignet ist, das Ergebnis anhand der mehreren Klassen-IDs mit den mehreren Klassen zu erzeugen.

39. Vorrichtung nach Anspruch 37, die weiterhin eine zweite Auswahleinrichtung (1813) umfasst, um Klassenabgriffe für die mehreren Klassifikationen gemäß einer Klassen-ID adaptiv auszuwählen.

40. Vorrichtung nach Anspruch 37, die weiterhin eine zweite Auswahleinrichtung (1813) umfasst, um Klassenabgriffe für die mehreren Klassifikationen gemäß einer Bewegungs-Klasse (1809) adaptiv auszuwählen.

41. Vorrichtung nach Anspruch 37, die weiterhin eine zweite Auswahleinrichtung (1813) umfasst, um Klassenabgriffe für die mehreren Klassifikationen gemäß einer Fehler-Klasse (1811) adaptiv auszuwählen.

42. Vorrichtung nach Anspruch 37, die weiterhin eine zweite Auswahleinrichtung (1813) umfasst, um Klassenabgriffe für die mehreren Klassifikationen gemäß einer Bewegungs-Klasse und einer Fehler-Klasse (1809, 1811) adaptiv auszuwählen.

43. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine räumliche Klasse (1807) zu erzeugen.

44. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Adaptive-Dynamikbereich-Kodierungs-Klasse (ADRC) (1807) zu erzeugen.

45. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Differenzielle-Pulscodemodulations-Klasse (DPCM) zu erzeugen.

46. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Vektorquantisierungs-Klasse (VQ) zu erzeugen.

47. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Diskrete-Kosinustransformations-Klasse (DCT) zu erzeugen.

48. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Bewegungs-Klasse (1809) zu erzeugen.

49. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Fehler-Klasse (1811) zu erzeugen.

50. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Räumliche-Aktivitäts-Klasse zu erzeugen.

51. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Dynamische-Bereichs-Klasse zu erzeugen.

52. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Standardabweichungs-Klasse zu erzeugen.

53. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Laplace-Klasse zu erzeugen.

54. Vorrichtung nach Anspruch 37, die weiterhin einen Klassengenerator umfasst, um eine Räumliche-Gradienten-Klasse zu erzeugen.

Revendications

1. Procédé pour rétablir un signal d'entrée détérioré (201) comprenant les étapes :

de détection d'un point de données détérioré du signal d'entrée détérioré ;
d'utilisation d'une structure adaptative de prises de classe et de plus d'un procédé de classification pour créer une pluralité de classes en se basant sur les caractéristiques d'une aire contenant le point de données ;
de classification de l'aire contenant le point de données relativement à la pluralité de classes (217) ;
de création d'un résultat de classification multiple à partir des classes dans lesquelles l'aire est classée (219), le résultat de classification multiple comportant un identifiant ;
de sélection d'un filtre correspondant au résultat de classification multiple en utilisant l'identifiant (224), le filtre comprenant des coefficients de filtre ;
de création d'un point de données non détériorées en filtrant l'aire avec le filtre correspondant au résultat de classification multiple (225) ; et
de fourniture en sortie d'un signal non détérioré (213) correspondant au signal d'entrée (201).

2. Procédé selon la revendication 1, dans lequel l'étape de création d'un résultat de classification multiple (219) comprend la création du résultat de classification multiple en se basant sur une pluralité d'identifiants de classe avec la pluralité de classes.

3. Procédé selon la revendication 1, comprenant en outre l'étape de sélection adaptative de prises de classe pour la pluralité de classifications en fonction d'un identifiant de classe (221).

4. Procédé selon la revendication 1, comprenant en outre l'étape de sélection adaptative de prises de classe pour la pluralité de classifications en fonction d'une classe de mouvement (1809).

5. Procédé selon la revendication 1, comprenant en outre l'étape de sélection adaptative de prises de classe pour la pluralité de classifications en fonction d'une classe d'erreur (1811).

6. Procédé selon la revendication 1, comprenant en outre l'étape de sélection adaptative de prises de classe pour la pluralité de classifications en fonction d'une classe de mouvement et d'une classe d'erreur (1813).

7. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe spatiale (1807).

8. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de codage adaptatif de plage dynamique (ADRC) (1807).

9. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de modulation différentielle par codage d'impulsions (DPCM).

10. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de quantification vectorielle (VQ).

11. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de transformation en cosinus discrète (DCT).

12. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de mouvement (1809).

13. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe d'erreur (1811).

14. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe d'activité spatiale.

15. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de plage dynamique.

16. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe d'écart type.

17. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de laplacien.

18. Procédé selon la revendication 1, comprenant en outre l'étape de création d'une classe de gradient spatial.

19. Article de fabrication destinée à être utilisé dans un système informatique pour rétablir un signal d'entrée détérioré (201), l'article de fabrication comprenant un support utilisable par un ordinateur comportant un moyen de code de programme lisible par un ordinateur incorporé dans le support, le moyen de code de programme comportant :

un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire détecter par l'ordinateur un point de données détérioré du signal d'entrée détérioré ;
un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire utiliser par l'ordinateur une structure adaptative de prise de classe et plus d'un procédé de classification pour créer une pluralité de classes en se basant sur les caractéristiques d'une aire contenant le point de données ;
un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire classer par l'ordinateur l'aire contenant le point de données relativement à la pluralité de classes (217) ;
un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur un résultat de classification multiple à partir des classes dans lesquelles l'aire est classée (219), le résultat de classification multiple comportant un identifiant ;
un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire sélectionner par l'ordinateur un filtre correspondant au résultat de classification multiple en utilisant l'identifiant (224), le filtre comprenant des coefficients de filtre ;
un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur un point de données non détériorées en filtrant l'aire avec le filtre correspondant au résultat de classification multiple (225) ; et
un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire fournir en sortie par l'ordinateur un signal non détérioré (213) correspondant au signal d'entrée (201).

20. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur le résultat de classification multiple en se basant sur une pluralité d'identifiants de classe avec la pluralité de classes (219).

21. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire sélectionner de manière adaptative par l'ordinateur des prises de classe pour la pluralité de classifications en fonction d'un identifiant de classe (221).

22. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire sélectionner de manière adaptative par l'ordinateur des prises de classe pour la pluralité de classifications en fonction d'une classe de mouvement (1809).

23. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire sélectionner de manière adaptative par l'ordinateur des prises de classe pour la pluralité de classifications en fonction d'une classe d'erreur (1811).

24. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire sélectionner de manière adaptative par l'ordinateur des prises de classe pour la pluralité de classifications en fonction d'une classe de mouvement et d'une classe d'erreur (1813).

25. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe spatiale (1807).

26. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de codage adaptatif de plage dynamique (ADRC) (1807).

27. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de modulation différentielle par codage d'impulsions (DPCM).

28. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de quantification vectorielle (VQ).

29. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de transformation en cosinus discrète (DCT).

30. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de mouvement (1809).

31. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe d'erreur (1811).

32. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe d'activité spatiale.

33. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de plage dynamique.

34. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe d'écart type.

35. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de laplacien.

36. Article de fabrication selon la revendication 19, comprenant en outre un moyen de code de programme lisible par un ordinateur incorporé dans le support utilisable par l'ordinateur pour faire créer par l'ordinateur une classe de gradient spatial.

37. Dispositif pour rétablir un signal d'entrée détérioré (1801) comprenant :

un moyen pour détecter un point de données détérioré du signal d'entrée détérioré ;
un moyen pour utiliser une structure adaptative de prise de classe et plus d'un procédé de classification pour créer une pluralité de classes en se basant sur les caractéristiques d'une aire contenant le point de données ;
un moyen pour classer (1807, 1809, 1811) l'aire contenant le point de données relativement à la pluralité de classes ;
un moyen pour créer un résultat de classification multiple à partir des classes dans lesquelles l'aire est classée, le résultat de classification multiple comportant un identifiant ;
un moyen pour sélectionner (1815) un filtre correspondant au résultat de classification multiple en utilisant l'identifiant, le filtre comprenant des coefficients de filtre ;
un moyen pour créer (1817) un point de données non détériorées en filtrant l'aire avec le filtre correspondant au résultat de classification multiple ; et
un moyen pour fournir en sortie (1821) un signal non détérioré (1823) correspondant au signal d'entrée (1801).

38. Dispositif selon la revendication 37, dans lequel le moyen pour créer le résultat de classification multiple agit en créant le résultat en se basant sur une pluralité d'identifiants de classe avec la pluralité de classes.

39. Dispositif selon la revendication 37, comprenant en outre un second moyen de sélection (1813) pour sélectionner de manière adaptative des prises de classe pour la pluralité de classifications en fonction d'un identifiant de classe.

40. Dispositif selon la revendication 37, comprenant en outre un second moyen de sélection (1813) pour sélectionner de manière adaptative des prises de classe pour la pluralité de classifications en fonction d'une classe de mouvement (1809).

41. Dispositif selon la revendication 37, comprenant en outre un second moyen de sélection (1813) pour sélectionner de manière adaptative des prises de classe pour la pluralité de classifications en fonction d'une classe d'erreur (1811).

42. Dispositif selon la revendication 37, comprenant en outre un second moyen de sélection (1813) pour sélectionner de manière adaptative des prises de classe pour la pluralité de classifications en fonction d'une classe de mouvement et d'une classe d'erreur (1809, 1811).

43. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe spatiale (1807).

44. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de codage adaptatif de plage dynamique (ADRC) (1807).

45. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de modulation différentielle par codage d'impulsions (DPCM).

46. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de quantification vectorielle (VQ).

47. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de transformation en cosinus discrète (DCT).

48. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de mouvement (1809).

49. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe d'erreur (1811).

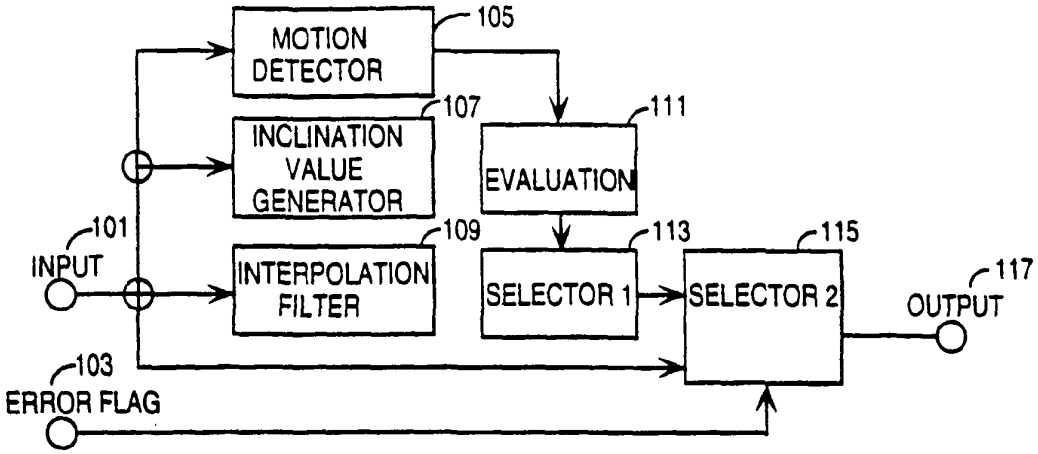
50. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe d'activité spatiale.

51. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de plage dynamique.

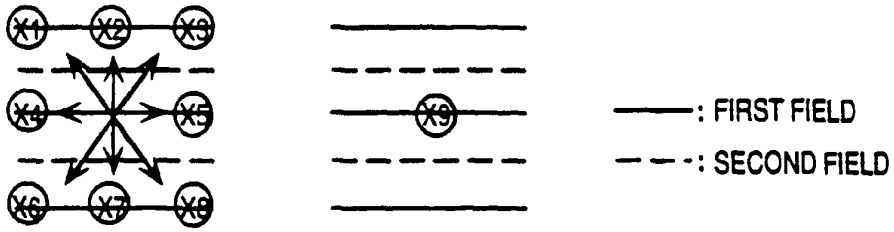
52. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe d'écart type.

53. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de laplacien.

54. Dispositif selon la revendication 37, comprenant en outre un générateur de classe pour créer une classe de gradient spatial.



(A) CONVENTIONAL ERROR RECOVERY METHOD



(B) FILTER TAP

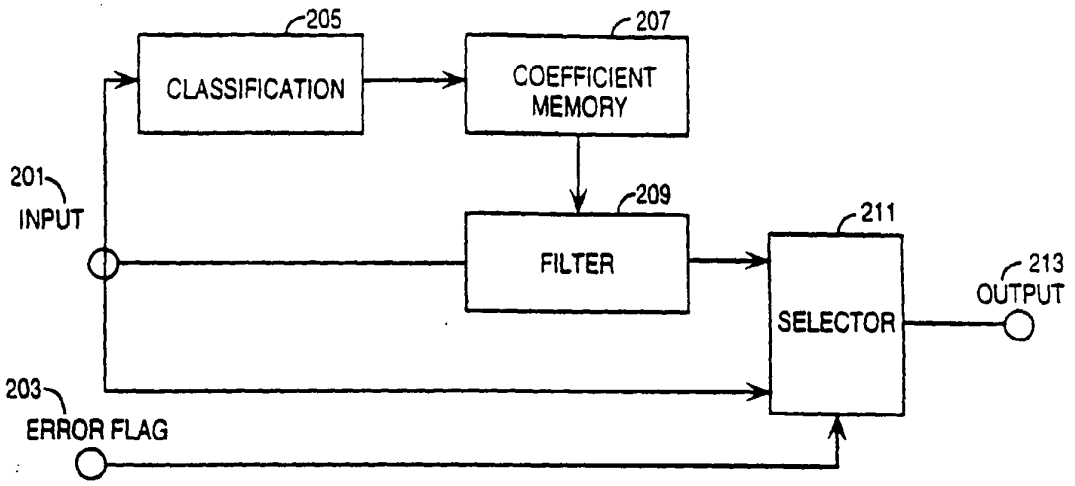
INCLINATION VALUE EI:

MOTION AREA:
E1 = |X1-X8| → Y1 + (X1=X8)/2
E2 = |X2-X7| → Y2 + (X2=X7)/2
E3 = |X3-X6| → Y3 + (X3=X6)/2
E4 = |X4-X5| → Y4 + (X4=X5)/2

STATIONARY AREA → Y5 = X9

(C) CORRESPONDENCE BETWEEN INCLINATION VALUE AND INTERPOLATION FILTER

FIGURE 1: CONVENTIONAL ERROR RECOVERY METHOD



(A) CLASSIFIED ADAPTIVE ERROR RECOVERY BLOCK DIAGRAM

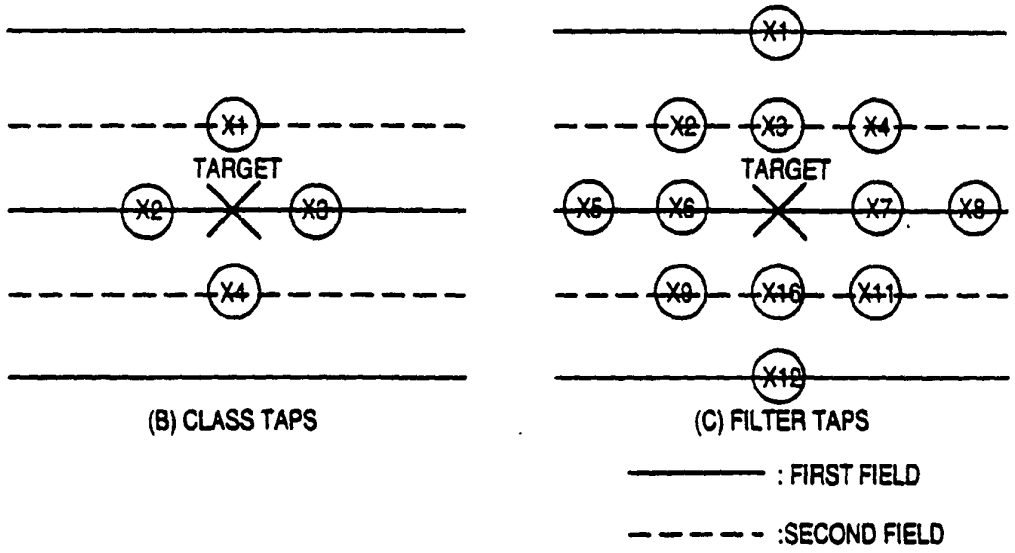


FIGURE 2 : CLASSIFIED ADAPTIVE ERROR RECOVERY METHOD

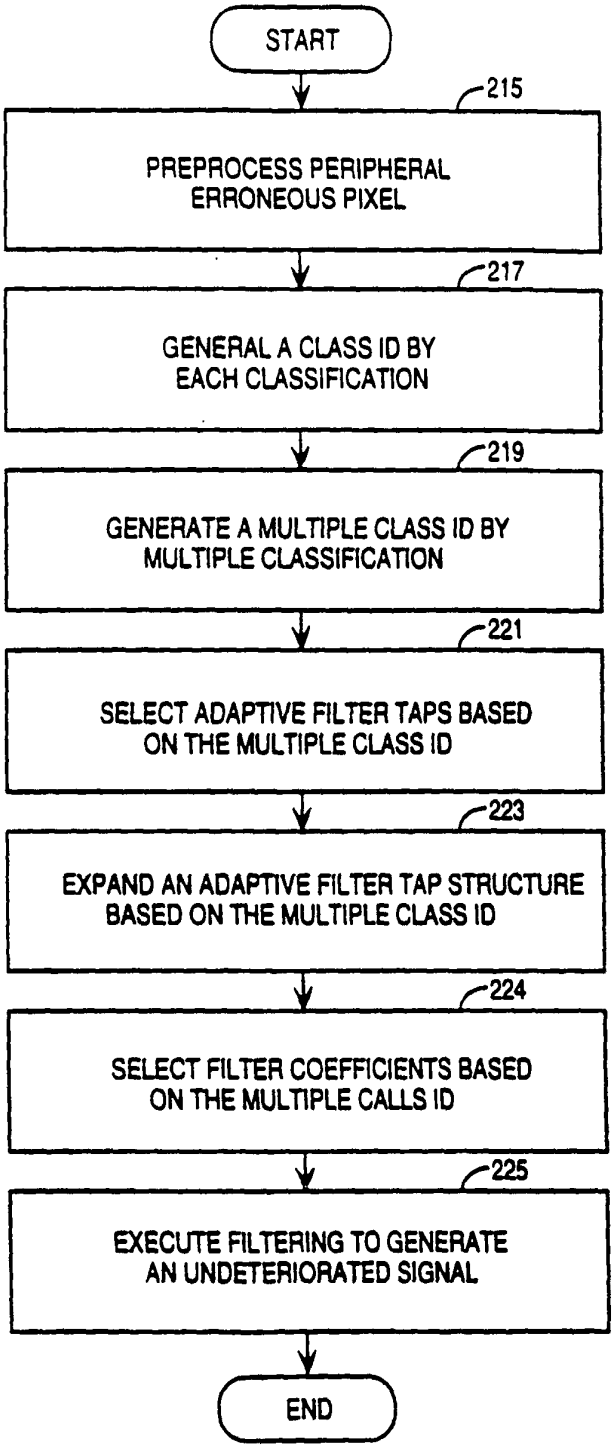

START
215
PREPROCESS PERIPHERAL ERRONEOUS PIXEL
217
GENERAL A CLASS ID BY EACH CLASSIFICATION
219
GENERATE A MULTIPLE CLASS ID BY MULTIPLE CLASSIFICATION
221
SELECT ADAPTIVE FILTER TAPS BASED ON THE MULTIPLE CLASS ID
223
EXPAND AN ADAPTIVE FILTER TAP STRUCTURE BASED ON THE MULTIPLE CLASS ID
224
SELECT FILTER COEFFICIENTS BASED ON THE MULTIPLE CALLS ID
225
EXECUTE FILTERING TO GENERATE AN UNDETERIORATED SIGNAL
END

FIG. 2D

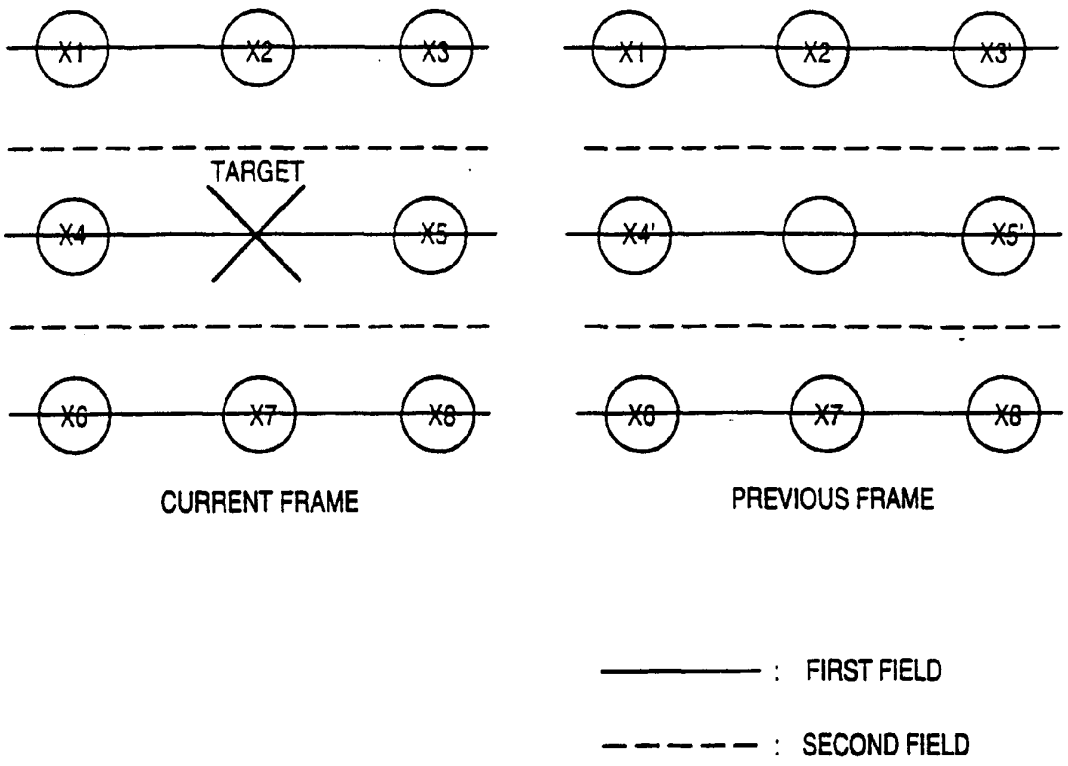


FIGURE 3 : MOTION CLASS TAP

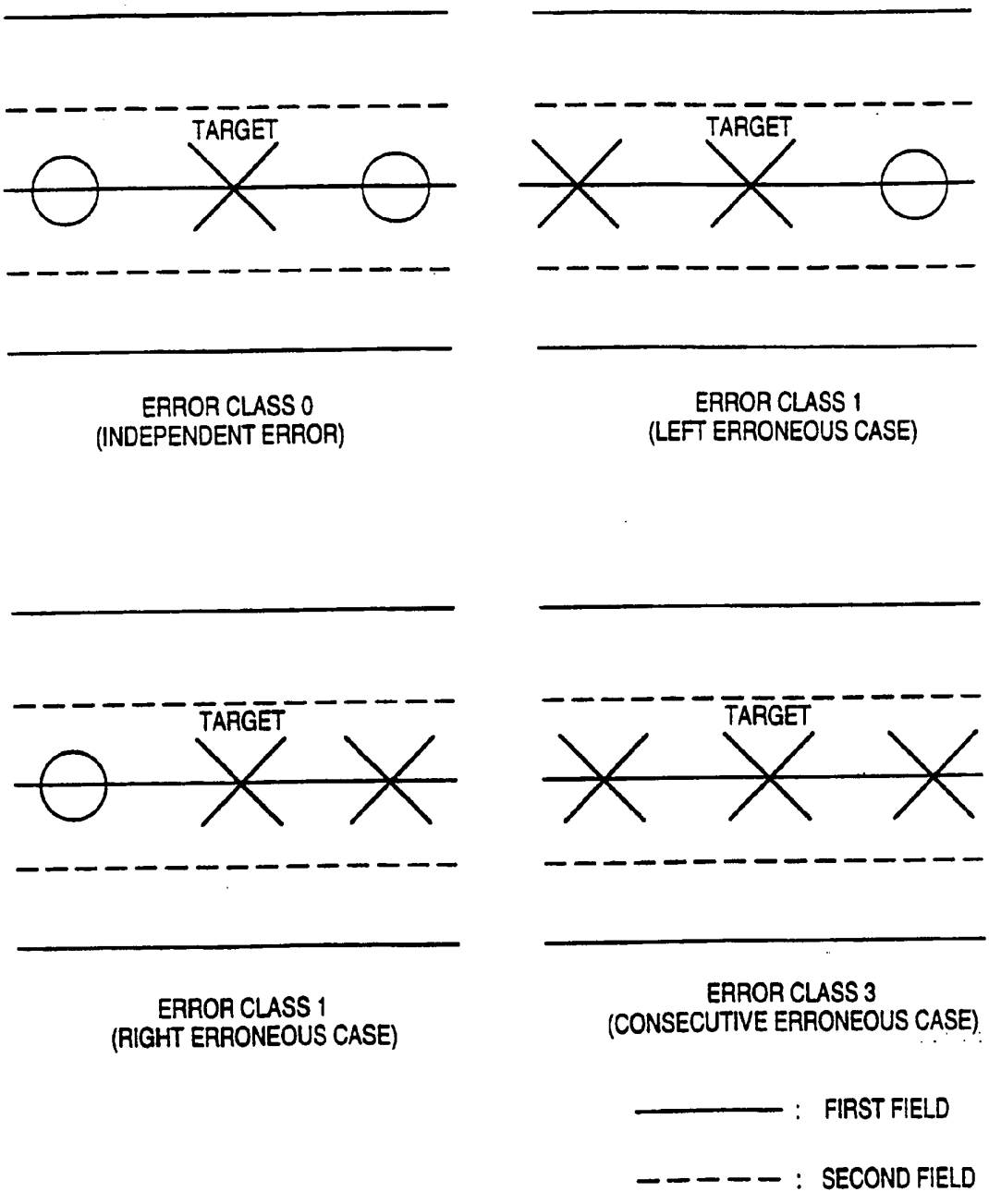


FIGURE 4 : ERROR CLASS TAP

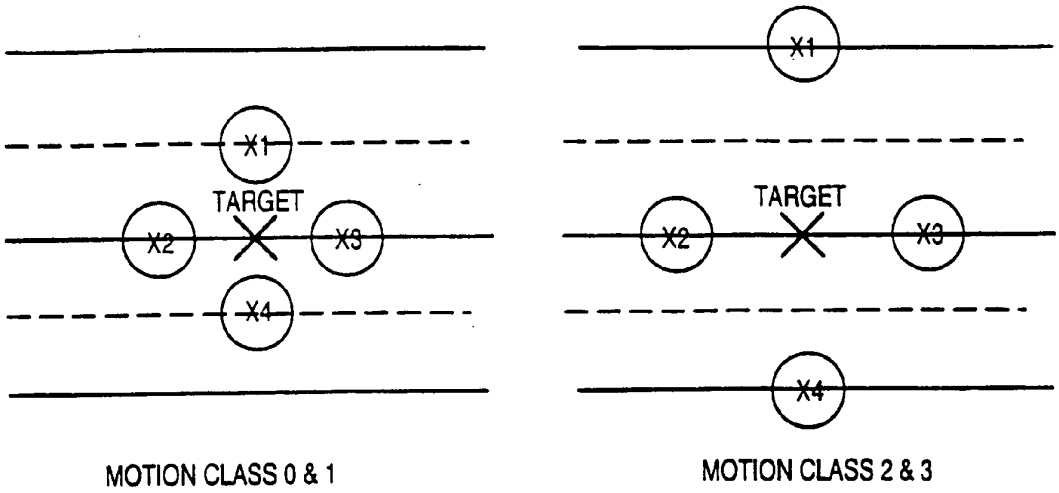
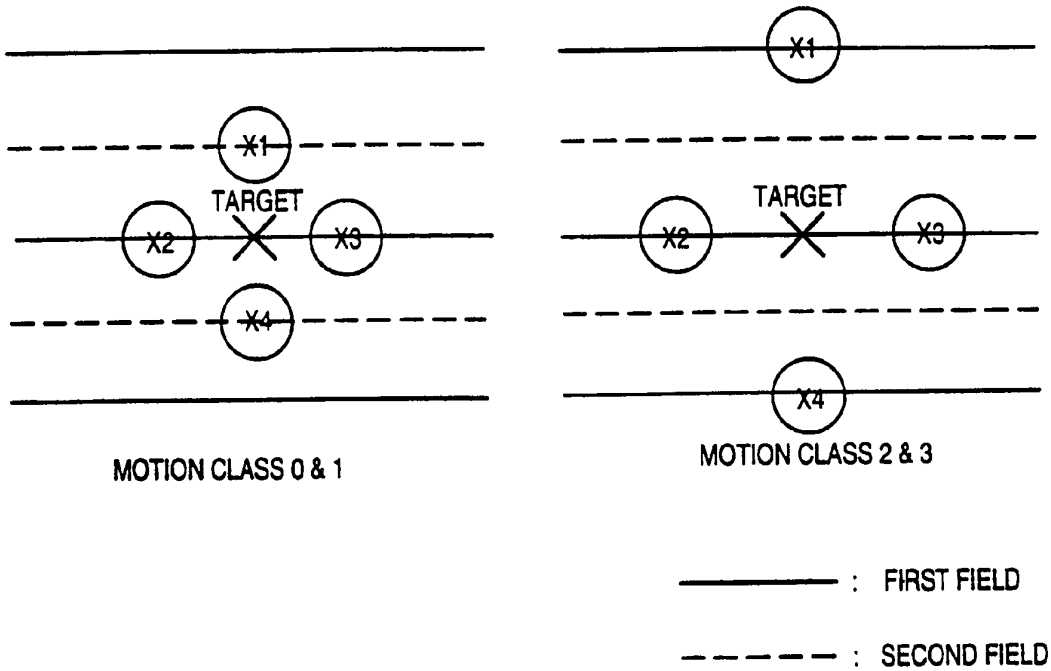
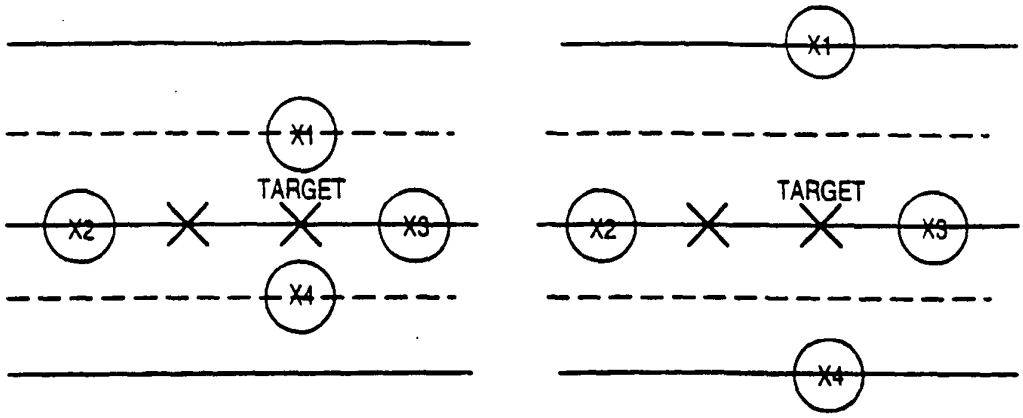


FIGURE 5 : ADAPTIVE SPATIAL CLASS TAP



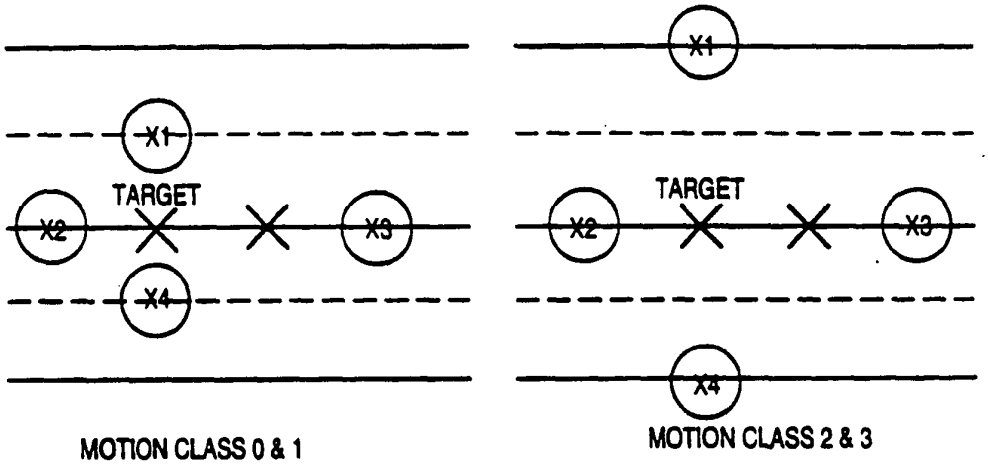
ERROR CLASS0 (INDEPENDENT ERRONEOUS CASE)

FIGURE 6 : ADAPTIVE SPATIAL CLASS TAP (ERROR CLASS0)



ERROR CLASS 1 (LEFT ERRONEOUS CASE)

FIGURE 7 : ADAPTIVE SPATIAL CLASS TAP (ERROR CLASS1)



ERROR CLASS 2 (RIGHT ERRONEOUS CASE)

FIGURE 8 : ADAPTIVE SPATIAL CLASS TAP (ERROR CLASS2)

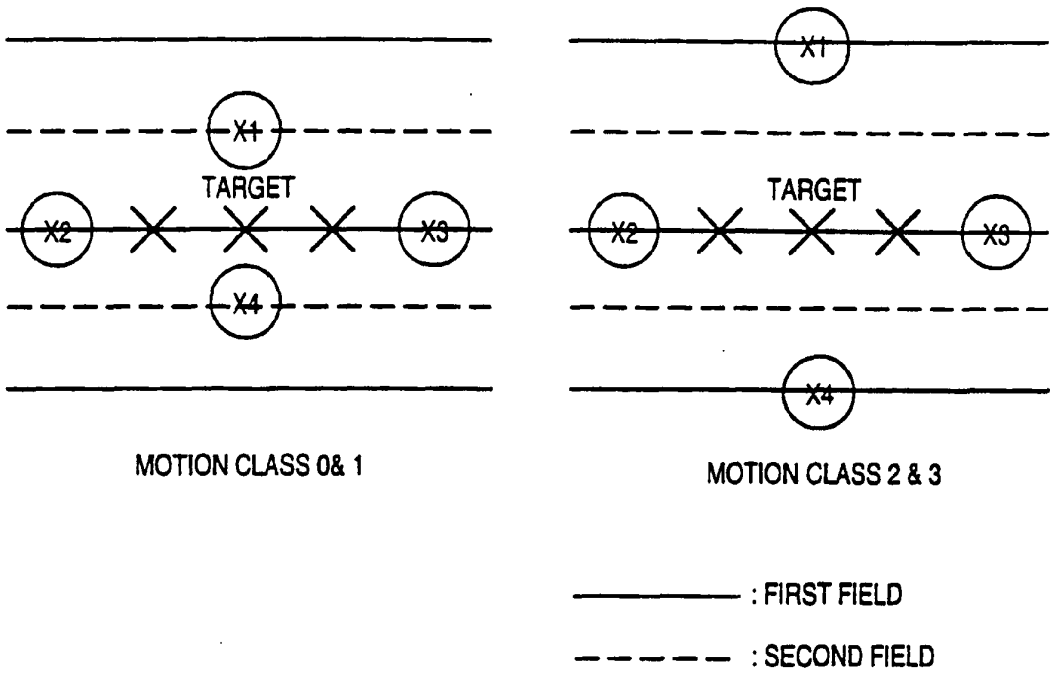


FIGURE 9 : ADAPTIVE SPATIAL CLASS TAP (ERROR CLASS3)

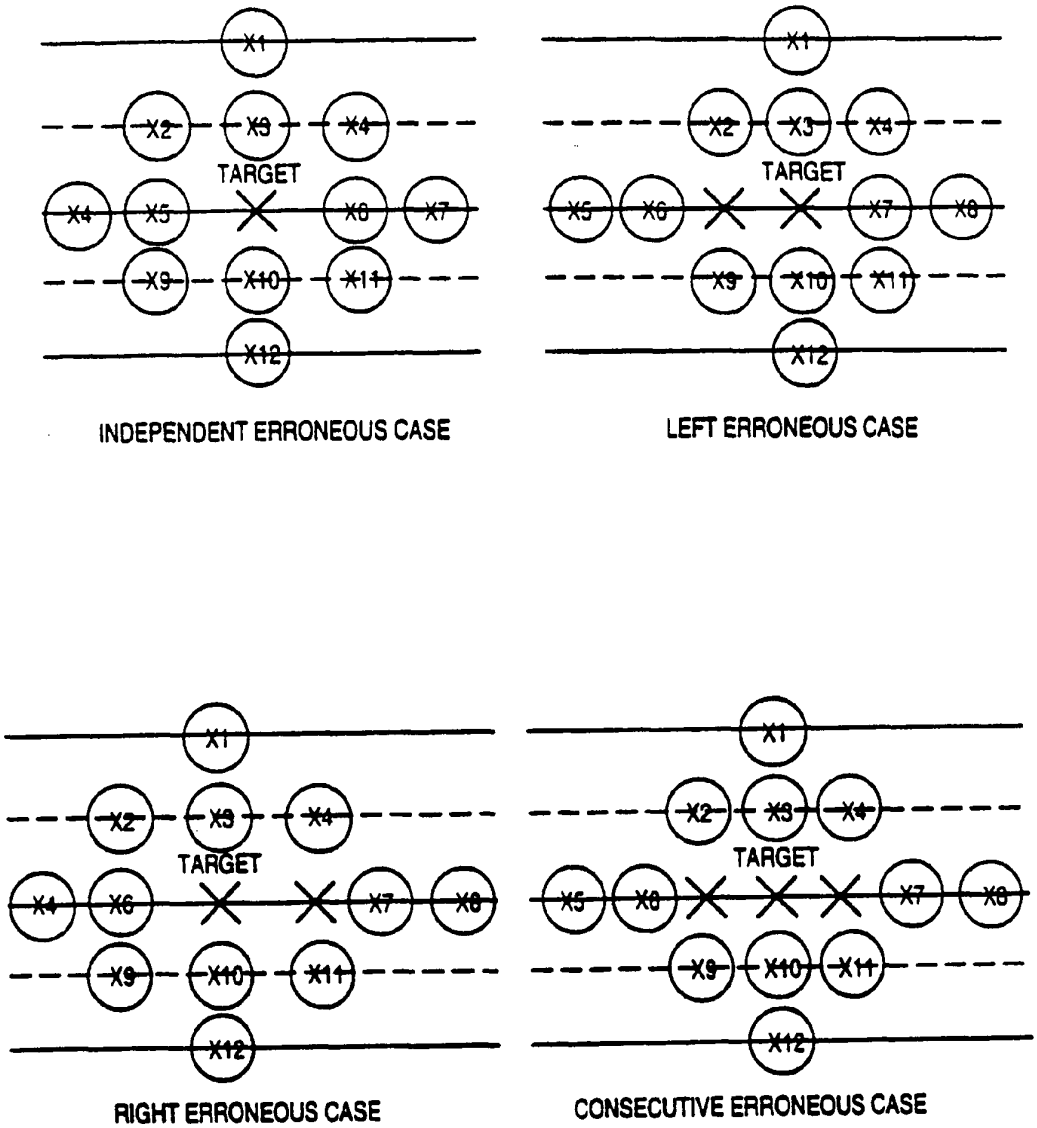


FIGURE 10 : ADAPTIVE FILTERTAP

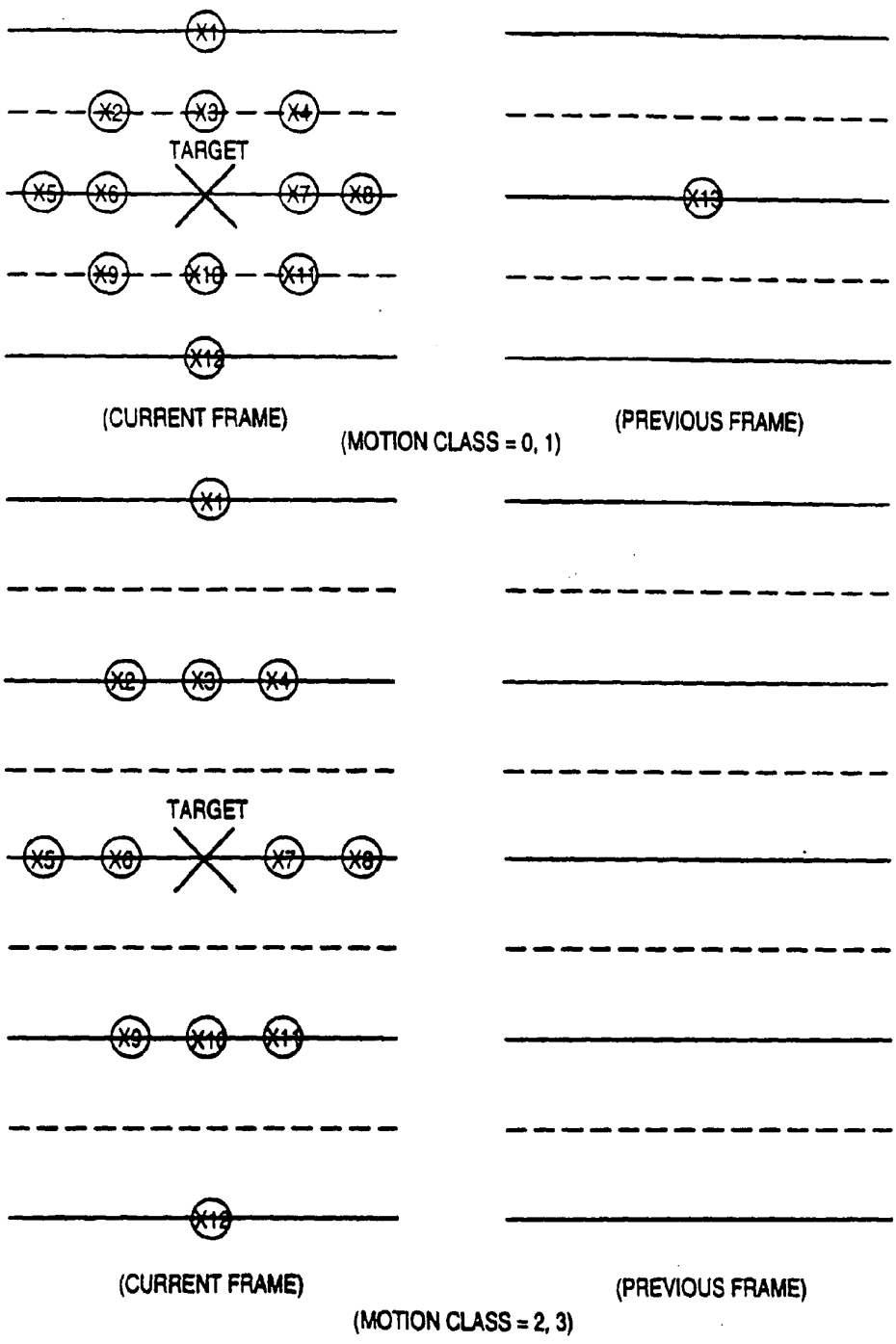


FIGURE 11 : ADAPTIVE FILTER TAP

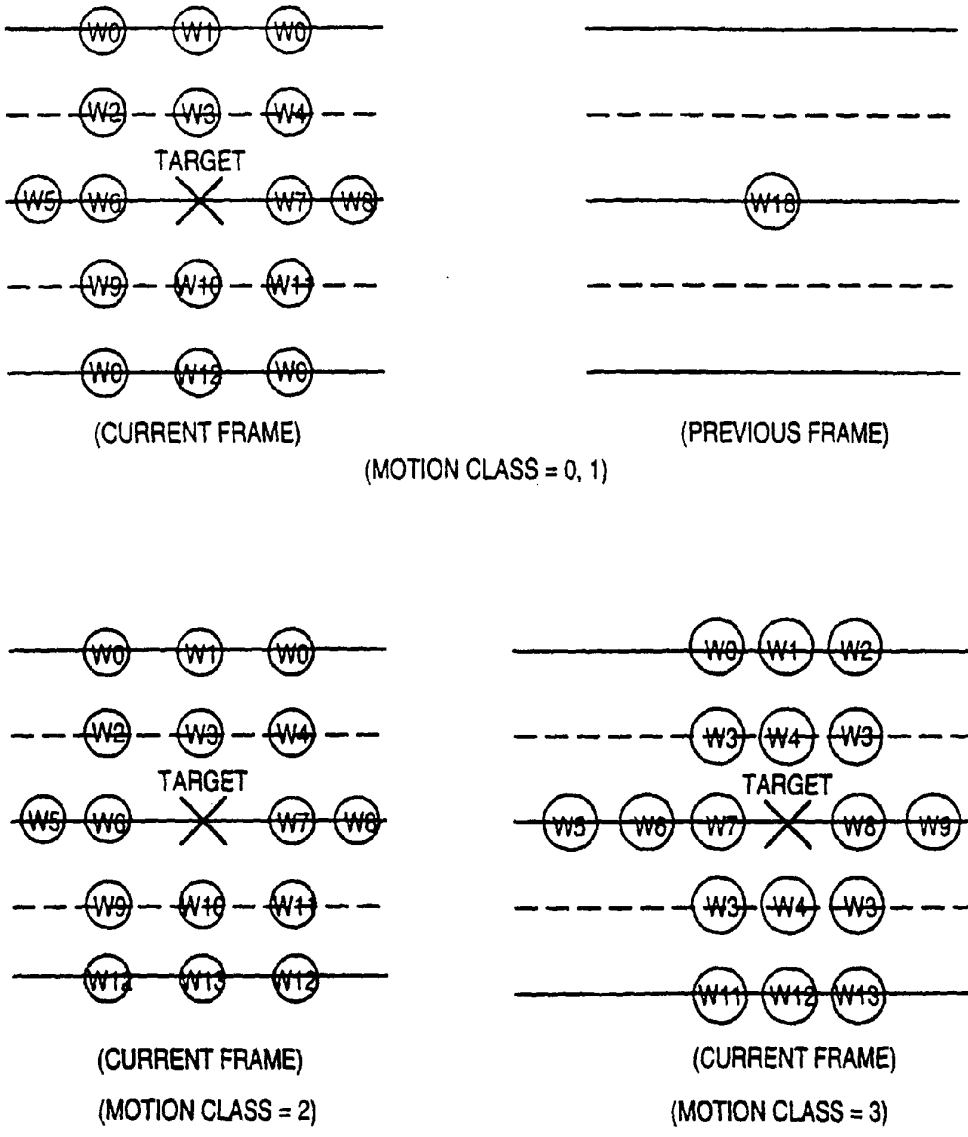


FIGURE 12 : ADAPTIVE FILTER TAP (ERROR CLASS0)

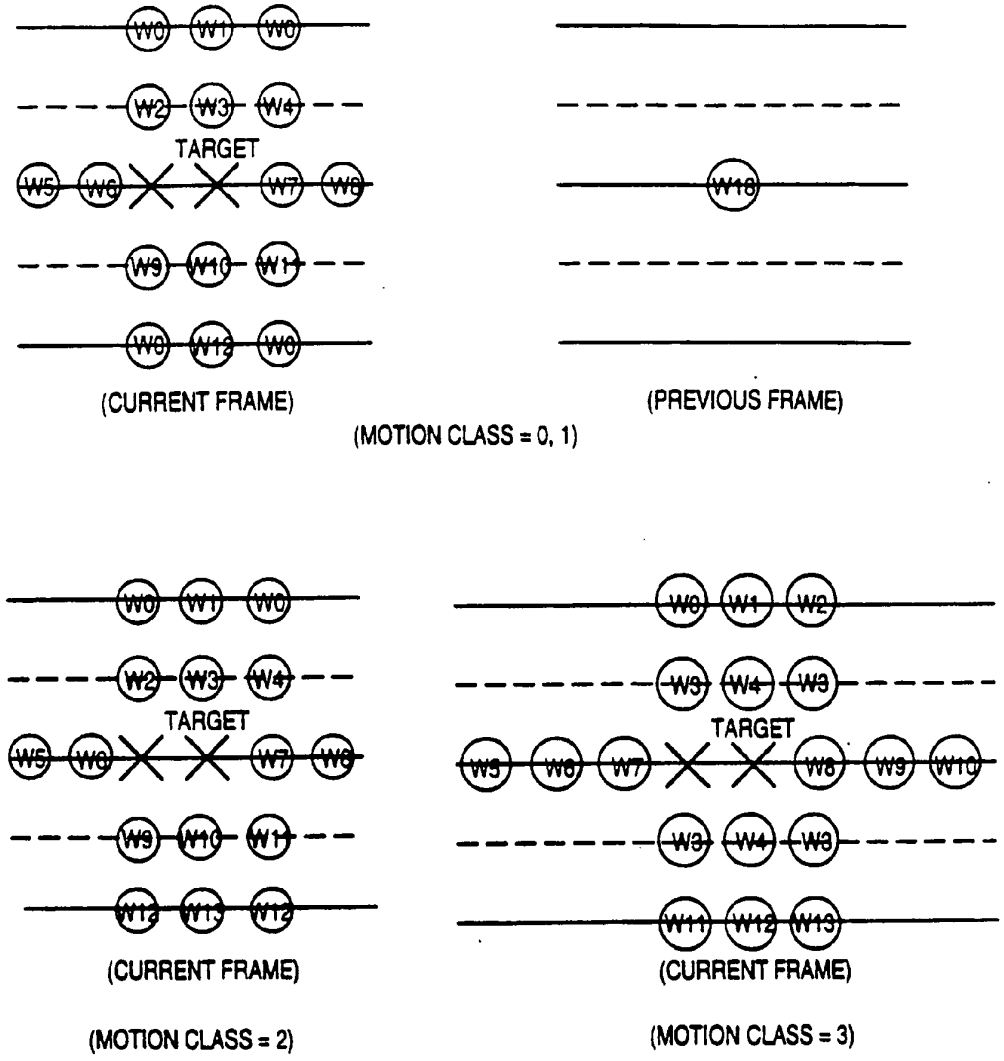
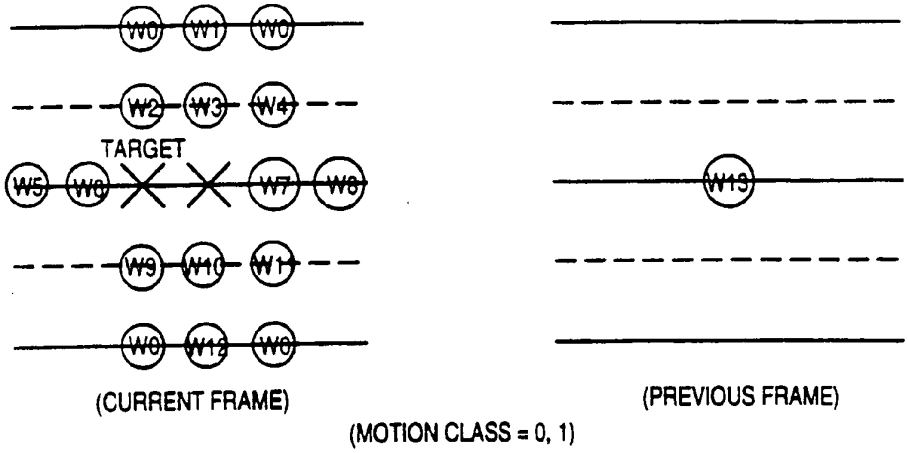


FIGURE 13 : ADAPTIVE FILTER TAP (ERROR CLASS1)



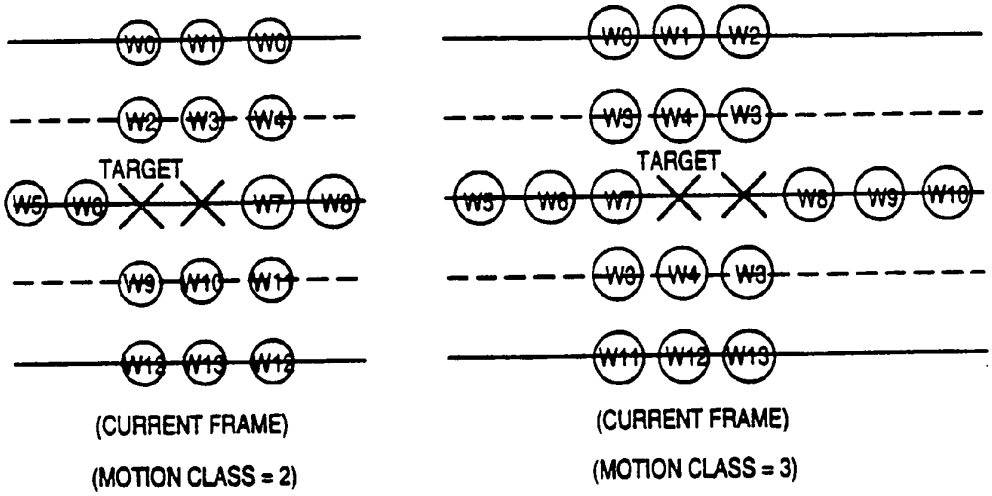


FIGURE 14 : ADAPTIVE FILTER TAP (ERROR CLASS2)

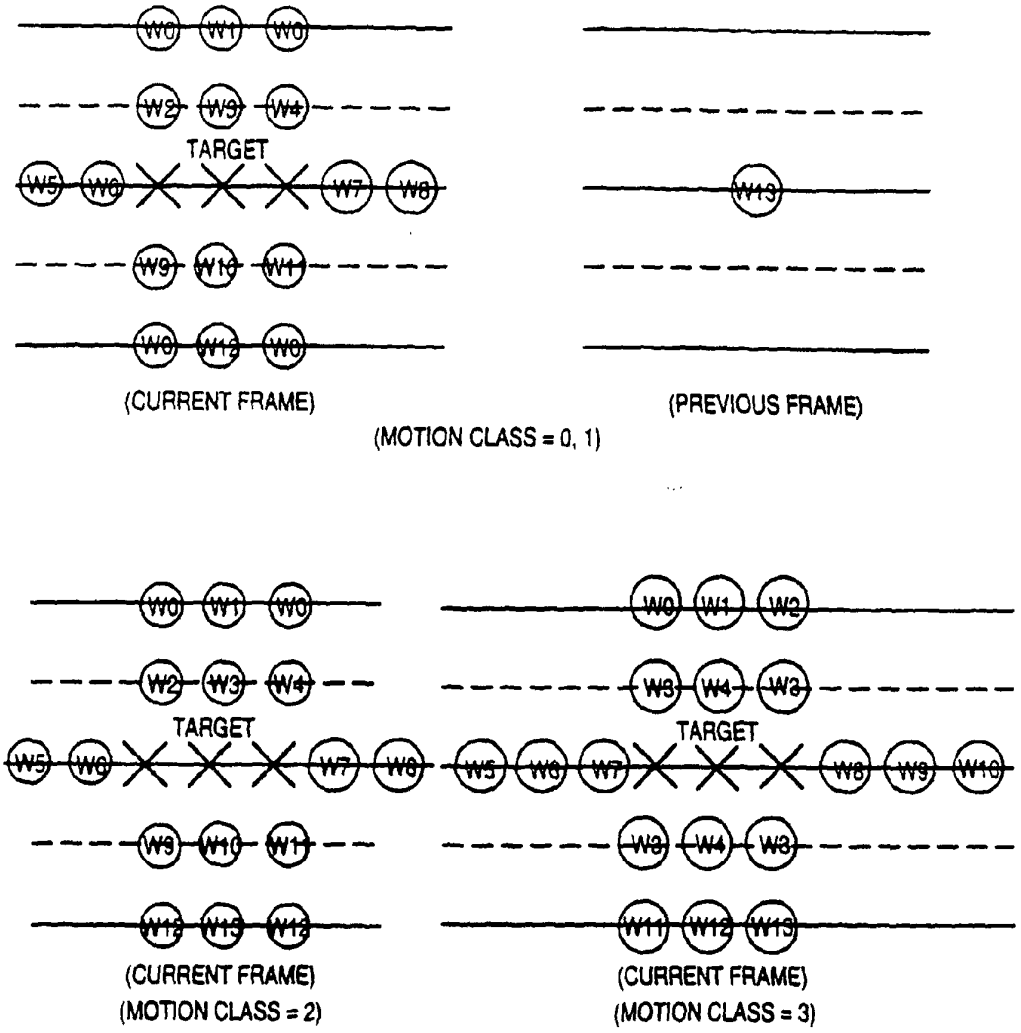


FIGURE 15 : ADAPTIVE FILTER TAP (ERROR CLASS3)

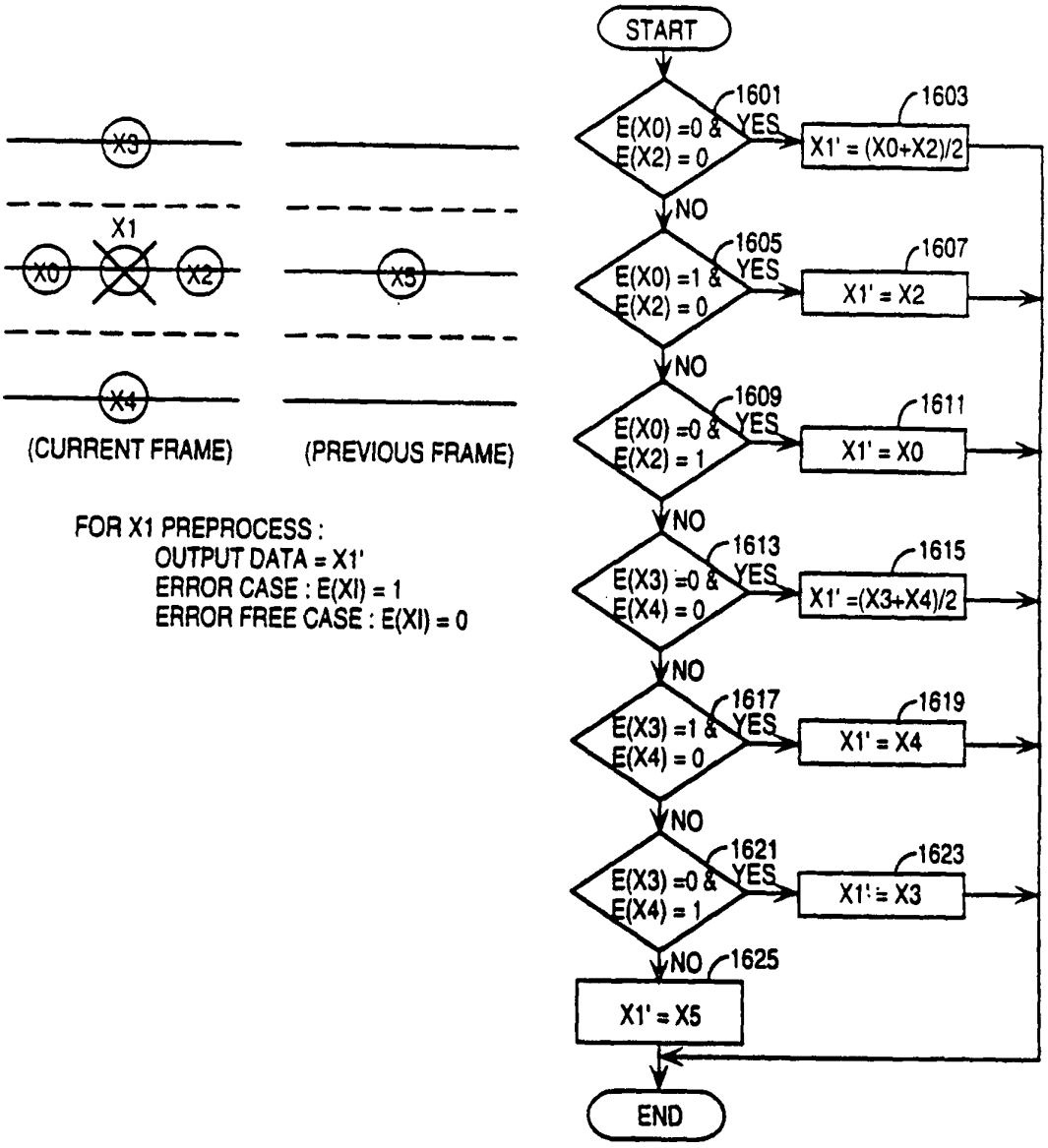


FIGURE 16 : PREPROCESSING ALGORITHM

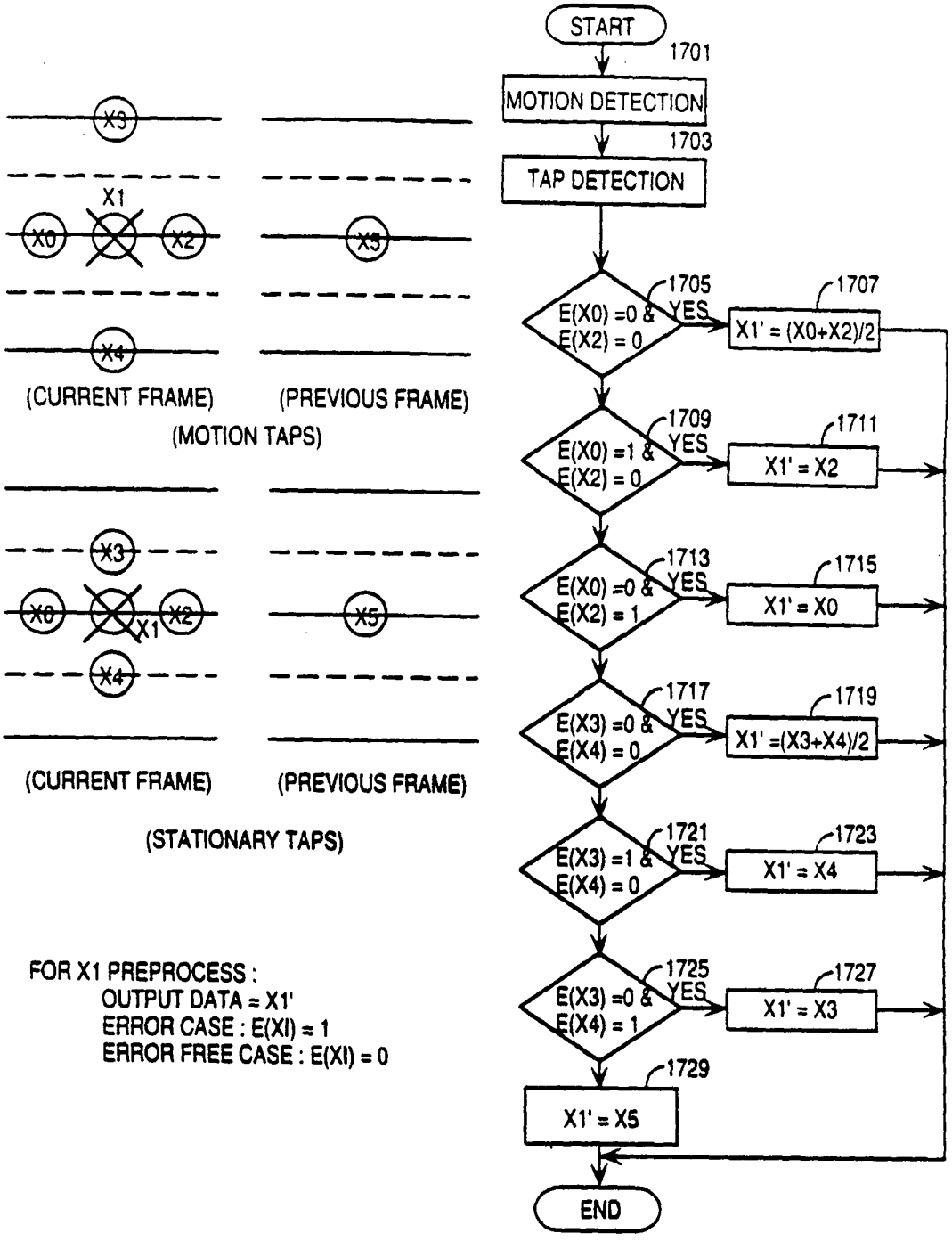


FIGURE 17 : PREPROCESSING ALGORITHM

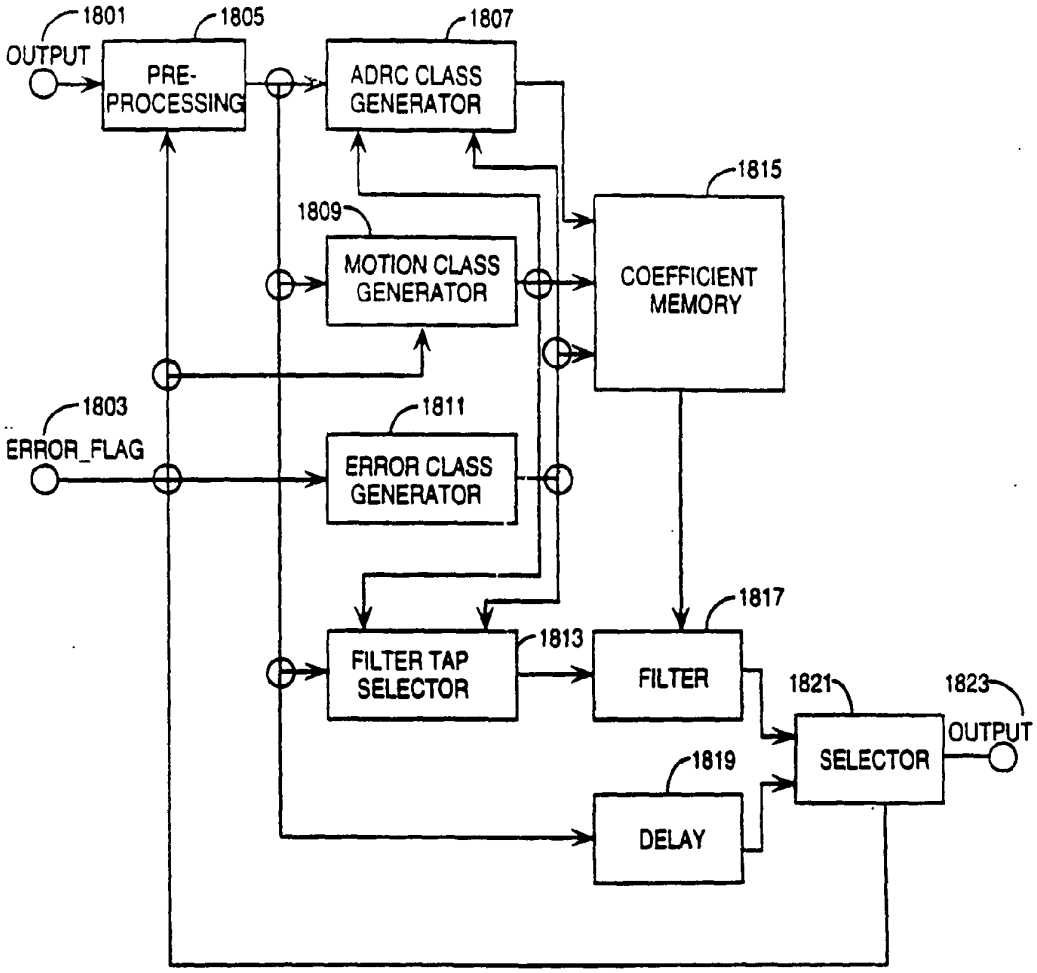


FIGURE 18 : SYSTEM BLOCK DIAGRAM

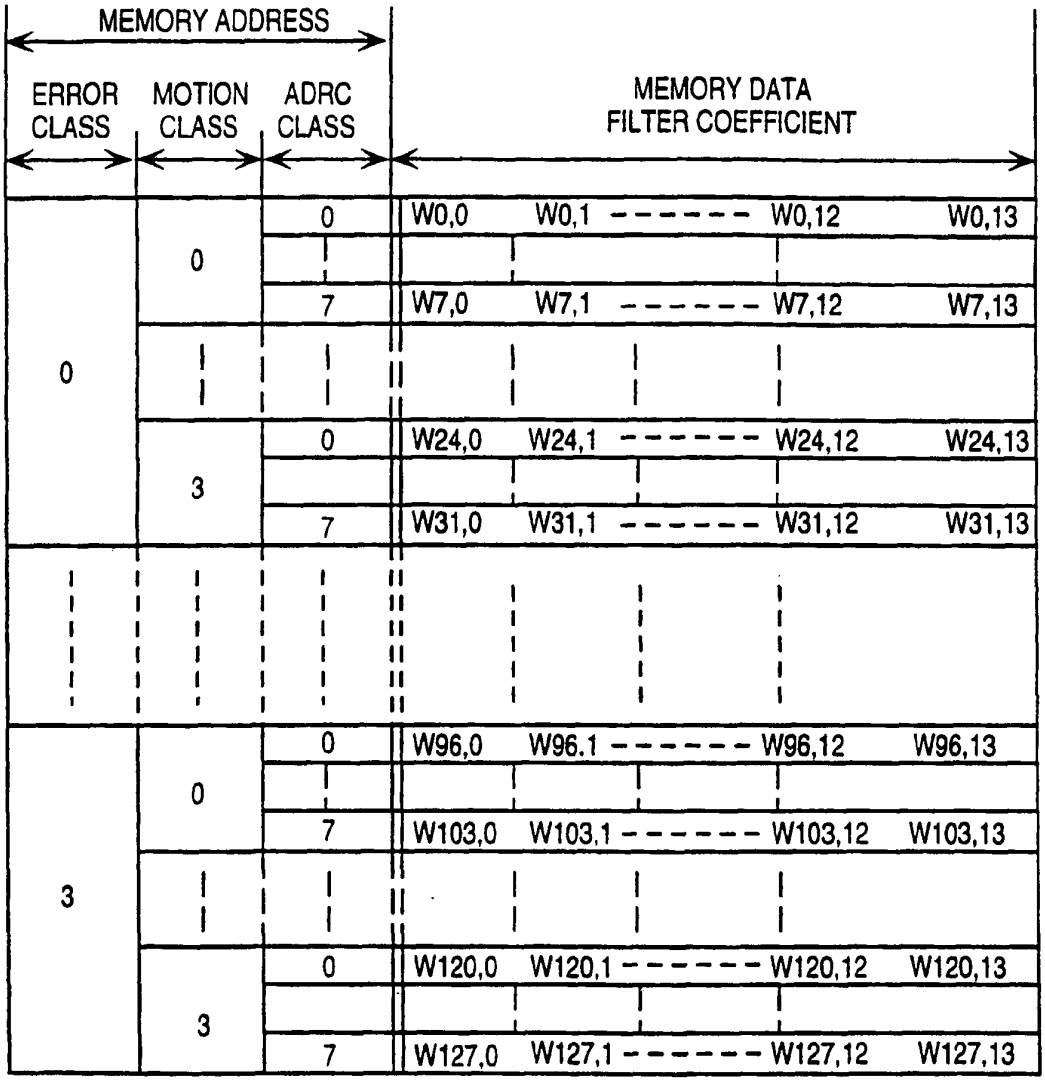


FIGURE 19 : COEFFICIENTS MEMORY CONTENTS

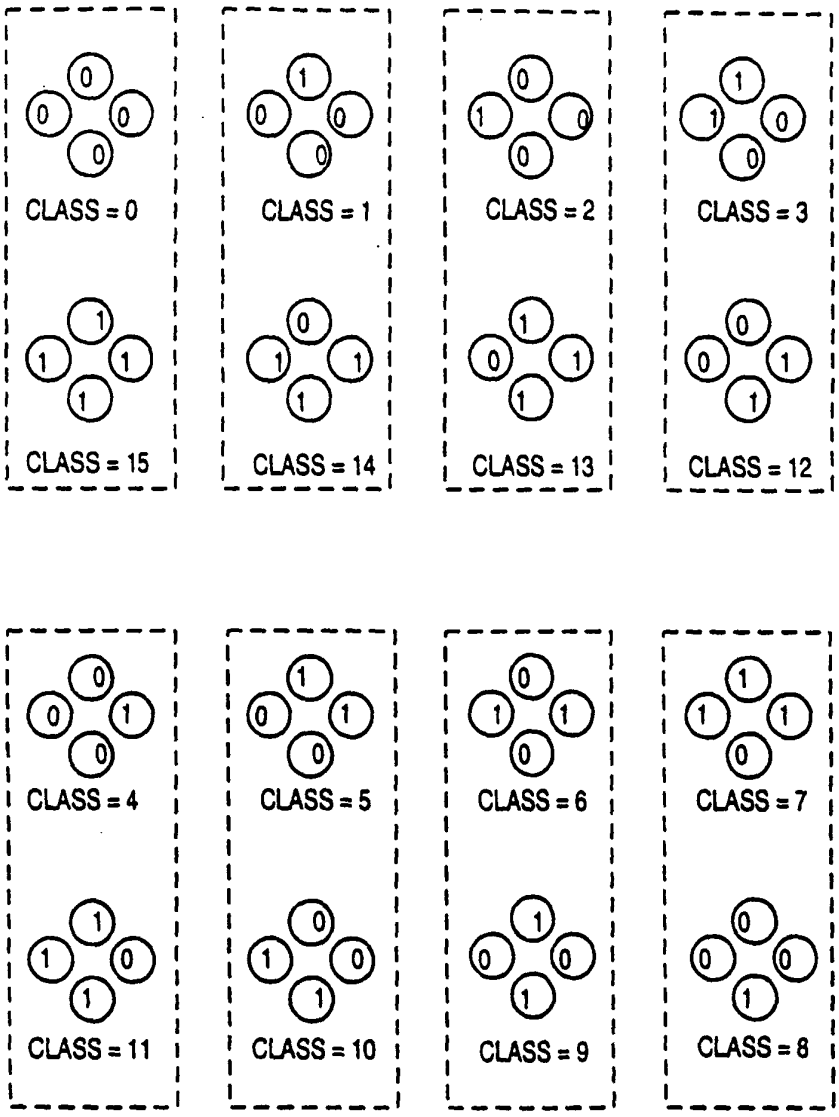


FIGURE 20 : ADRC CLASS REDUCTION

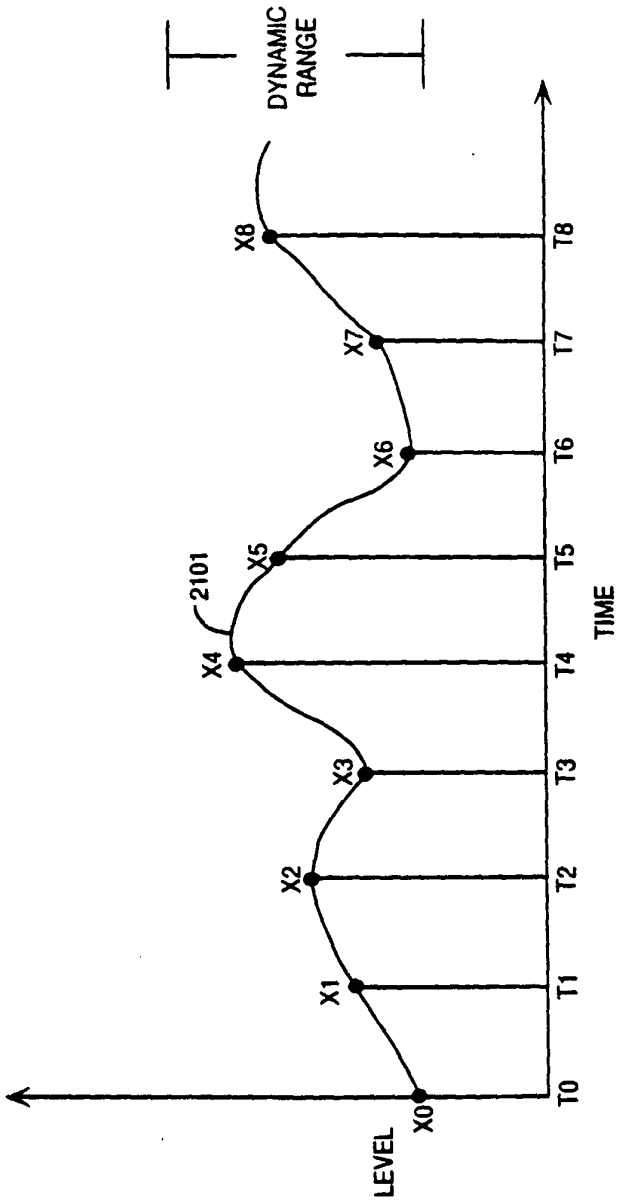

DYNAMIC RANGE
LEVEL
TIME
X0
X1
X2
X3
X4
X5
X6
X7
X8
T0
T1
T2
T3
T4
T5
T6
T7
T8
2101

FIG. 21