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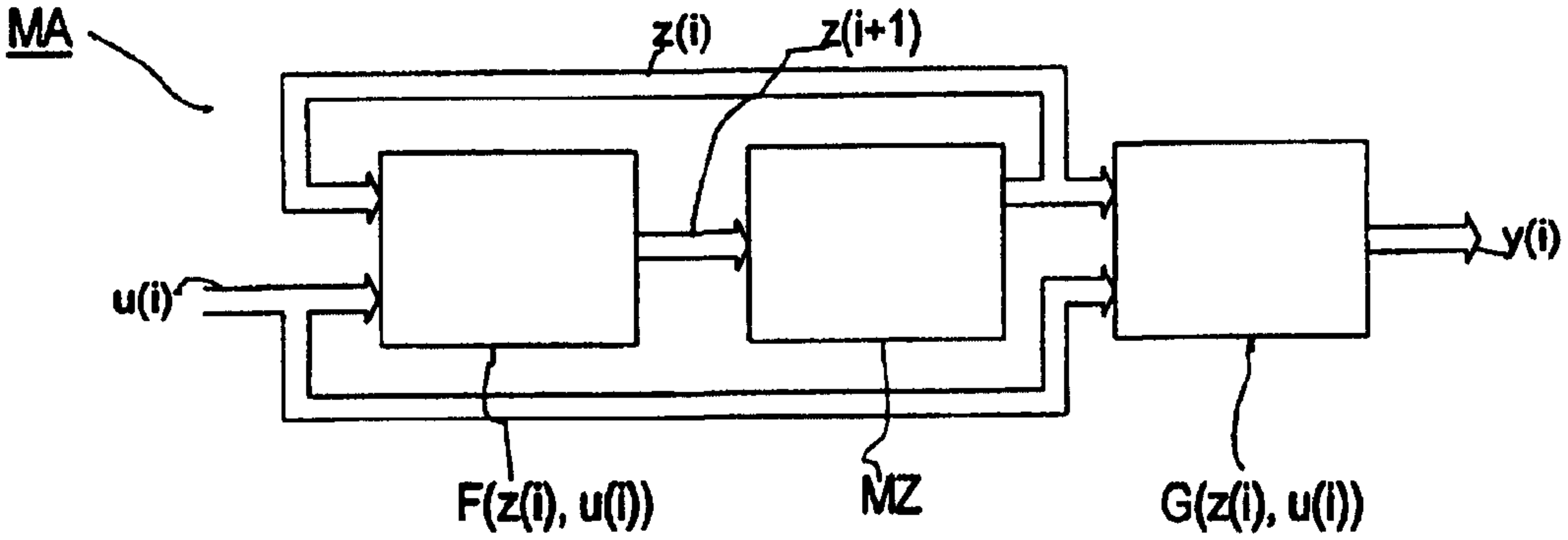
(54) PROCEDE POUR PARAMETRER UN AUTOMATE A LOGIQUE FLOUE QUI COMPARE UN SIGNAL DE MESURE A UN SIGNAL MODELE

(54) PROCESS FOR PARAMETERING A FUZZY AUTOMATON THAT COMPARES A MEASUREMENT SYSTEM TO A PATTERN SIGNAL



(57) Le procédé décrit permet de paramétrer automatiquement un automate à logique floue par génération de règles de transformation qui comprennent des règles de transition, d'arrêt, de retour en arrière et de réinitialisation des états de l'automate à logique floue qui représentent des probabilités de reconnaissance. L'avantage de ce procédé est que les règles de transformation qui servent à paramétrer l'automate à logique floue sont générées de manière entièrement automatique par l'ordinateur. Même lorsque les signaux modèle changent souvent, on peut changer les paramètres de l'automate à logique floue de manière rapide, simple et souple.

(57) The disclosed process enables a fuzzy automaton to be automatically parametered by generating transformation rules which include transition, stop, return and reset rules for the individual states of the fuzzy automaton which represent recognition probabilities. The advantage of the disclosed process is that it allows transformation rules for parametering the fuzzy automaton to be generated by the computer in a totally automatic manner. Even when the pattern signals change frequently, the parameters of the fuzzy automaton can be quickly, easily and flexibly altered.

Abstract

Method for configuring a fuzzy automatic-control device which is used for comparing a measurement signal with a pattern signal

The method according to the invention is used for automatically configuring a fuzzy automatic-control device, in the form of generating transformation criteria. These transformation criteria have change, stop, jump-back and reset rules for the individual states of the fuzzy automatic-control device that represent recognition probabilities. The advantage of the method according to the invention is that transformation criteria for configuring fuzzy automatic-control devices are produced fully automatically by the arithmetic and logic unit. Even if the pattern signals change frequently, the fuzzy automatic-control device can thus be reconfigured quickly, without complications and flexibly.

FIG 1

Description

Method for configuring a fuzzy automatic-control device which is used for comparing a measurement signal with a pattern signal

WO 96/31 304 discloses a device for early break-out recognition in continuous casting plant. To achieve early recognition of break-out, the surface temperature of the cast strand is detected with the aid of temperature sensors, which are arranged distributed in a mold around the strand and is subsequently evaluated. For this purpose, each of the temperature sensors is assigned a pattern recognition device, which uses the detected temperature and an internal state variable which represents the previous temperature profile to update the internal state variable on the basis of fuzzy conclusions, and to produce, on the output side, a current predicted value for the break-out probability. The pattern recognition device includes a fuzzy control unit based on fuzzy logic. In this case, the fuzzy control unit contains rules in the form of tables, which are based on linguistic values of the input variables, for example the temperature. The rules are used to define the preconditions under which the pattern recognition device changes or retains the internal state, that is to say the processing state of the fuzzy control unit, and thus the current predicted value for the break-out probability.

A disadvantage of the known pattern recognition device is that the fuzzy rules implemented in the fuzzy logic have to be produced (by hand) by a specialist. Since a complete "set" of the rules must be designed for each processing state of the fuzzy control unit, configuring the fuzzy logic in the known pattern recognition device is tedious and time-consuming.

It is also disadvantageous that pattern recognition device fuzzy logic configured with rules in this way can recognize only one specific pattern. If the pattern recognition device is intended to recognize a new, different pattern, for example after a change to the continuous casting plant, then new rules for configuring the fuzzy logic must once again be designed by hand, by a specialist and based on his specialist knowledge.

The invention is now based on the object of specifying a method for using a programmable arithmetic and logic unit to configure a fuzzy automatic-control device which is used for comparing a measurement signal with a pattern signal.

The object is achieved by the method specified in claim 1, as well as the use of the method specified in claim 10, in a device for early break-out recognition in continuous casting plant.

The solution according to the invention for configuring a fuzzy automatic-control device has the advantage that the device can be configured fully automatically by using the arithmetic and logic unit to produce transformation criteria. The arithmetic and logic unit must have predefined for it the pattern signal to be recognized, or the pattern signals to be recognized, in order to allow it to be configured.

The process according to the invention of configuring the fuzzy automatic-control device has, in particular, the advantage that, if the pattern signals change frequently, the fuzzy automatic-control device can be reconfigured quickly, without complications and flexibly. The "recording" of a pattern signal in the fuzzy automatic-control device can thus be carried out even without any specific specialist knowledge.

Further advantageous embodiments of the invention are specified in the corresponding dependent claims.

The invention will be explained in more detail in the following text with reference to the exemplary embodiments, which are illustrated in the figures that are described briefly below and in which:

FIG 1	shows, by way of example, a basic design of a fuzzy automatic-control device,
FIG 2	shows, by way of example, a fuzzy automatic-control device for comparing a measurement signal with a pattern signal,
FIG 3	shows, by way of example, a state graph for the fuzzy processing states of a fuzzy automatic-control device,
FIG 4	shows an example of the signal profile of a signal f and its derivative f', in which the areas outlined by dashed lines denote selected points on the signal profiles,
FIG 5	shows, by way of example, the input value range of the fuzzy automatic-control device, with the signal profiles f and f' illustrated in Figure 4 forming the pattern signal T in the form of a trajectory,
FIG 6	illustrates the input value range from Figure 5 with the feature ranges illustrated by gray areas, and
FIGS 7a-7h	show, by way of example, Karnaugh maps of the transformation criteria, defined according to the invention by the arithmetic and logic unit, for the individual processing states of the fuzzy automatic-control device.

Figure 1 shows, by way of example, a fundamental design MA of a fuzzy automatic-control device with an input vector u(i). A first fuzzy logic device F(z(i), u(i)) uses the input vector u(i) and a buffer-stored internal state vector z(i) to produce an updated state vector z(i+1), which is buffer-stored in a memory element MZ. The buffer-stored state vector z(i) and the input vector u(i) are linked to one another in a second fuzzy logic device G(z(i), u(i)) to form an output vector y(i).

By way of example, Figure 2 shows a fuzzy automatic-control device FA with a fuzzy logic device FZ. This corresponds to the fundamental design MA, shown in Figure 1, of a fuzzy automatic-control device FA, in which case the first fuzzy logic device F(z(i), u(i)) and the second fuzzy logic device G(z(i), u(i)) have a matching transfer function, that is to say FZ = F(z(i), u(i)) = G(z(i), u(i)). Furthermore, the input vector u(i) in the example in Figure 2 comprises the input variables of a first signal u(t) and of a second signal u'(t), which, for example, is the derivative of the first signal u(t) with respect to time. In the example in Figure 2, the fuzzy automatic-control device FA has only a single output variable y(i) = P(i+1), which is buffer-stored in a memory element MZ and is fed back as an internal state vector P(i) to the input of the fuzzy logic device FZ. The buffer-stored, internal state vector P(i) in this case corresponds to the recognition probability that a specific signal profile of the input variables u(t) and u'(t) is already present. This is achieved according to the invention by appropriately configuring PA the fuzzy logic device FZ by means of a programmable arithmetic and logic unit RE.

The fuzzy automatic-control device FA and the programmable arithmetic and logic unit RE may be either in the form of hardware or in the form of software. The fuzzy automatic-control device FA and the arithmetic and logic unit RE may, in this case, and in particular, be implemented as separate units but, preferably, also in a single apparatus, for example by means of two computer programs installed on a computer.

The fuzzy automatic-control device FA illustrated in Figure 2 is preferably a fuzzy automatic-control device of the "Sugeno" type. The fuzzy logic device FZ in this case and in particular produces fuzzification of the input variables, which is output via an arithmetic and logic unit and, in particular, a subsequent defuzzification device as a recognition level P(i+1). The inference is preferably drawn using the max-min method, and the defuzzification process is based on the centroid method for singletons. The recognition level P(i+1) is a measure of the probability that a specific signal profile, defined by the configuration PA, of the input variables u(t) and u'(t) is present. The buffer-storage and feeding back of the internal state vector P(i) determined in the respectively preceding time step makes it possible for the fuzzy logic device FZ to compare the actual values of the input variables u(t) and u'(t) with the profile of the pattern signal defined by the configuration PA.

By way of example, Figure 3 shows a fuzzy state graph for the fuzzy automatic-control device FA. The nodes of the state graph in this case map the possible processing states Z1, Z2, ..., Zn-1, Zn in which the fuzzy automatic-control device FA may be. The higher the respective processing state Z1..Zn that the fuzzy automatic-control device FA is currently in, the greater is the probability that a specific signal profile of the input variables u(t) and u'(t) is already present. In this case, the processing states Z1..Zn are described, in particular, by so-called "linguistic variables" in the fuzzy logic device FZ, which are subsequently used to form the recognition level P(i+1). The processing states Z1..Zn are described, in particular, as being "fuzzy" since, in contrast to binary automatic-control devices, the fuzzy automatic-control device FA can assume a plurality of operating states at the same time, with specific probability proportions.

The conditions for the fuzzy automatic-control device FA to change between the individual processing states Z1..Zn are described by transformation criteria, which are indicated in Figure 3 by arrows with the reference symbols A1..An-1,B2,..,Dn. The transformation criteria in this case define whether the fuzzy automatic-control device FA retains or changes its processing state. The transformation criteria are composed, in particular, of change rules A1..An-1 in response to which the fuzzy automatic-control device FA changes from a current processing state to a next-higher processing state, stop rules B2..Bn-1 in response to which the fuzzy automatic-control device FA remains in a current processing state, jump-back rules C3..Cn-1 in response to which the fuzzy automatic-control device FA jumps back from a current processing state to a next-lower processing state, as well as reset rules D1..Dn in response to which the fuzzy automatic-control device FA jumps back from a current processing state to the lowest processing state, that is to say the first processing state Z1.

Figure 4 shows an example of the signal profile of a signal f and its derivative f' with respect to time. The signals f and f' are preferably shown scaled in normalized form and, in the following examplary embodiment, are used for configuring the fuzzy automatic-control device FA illustrated in Figure 2. The latter is used to compare a measurement signal, for example the actual values of the input variables u(t) and u'(t), with a pattern signal. In the example in Figure 4, the pattern signal is formed by the illustrated signals f and f'. The pattern signal is not necessarily composed of a basic signal and its first derivative, but may also have higher derivatives or other signals.

According to the invention, the programmable arithmetic and logic unit RE selects points K1..K7 on the profile of the pattern signal. The selected points K1..K7 are, in particular, also denoted as being characteristics of the pattern signal. The points may be, for example, randomly selected points or points taken equidistantly from the profile of the pattern signal. To allow the fuzzy automatic-control device FA to carry out signal comparison efficiently and quickly, the complete signal profile of the pattern signal is thus not used for the comparison with the measurement signal. In an advantageous embodiment of the invention, the arithmetic and logic unit RE defines the selected points K1..K7 in such a manner that they are characteristic of the profile of the pattern signal. The selected points K1..K7 on the signal profile of the pattern signal advantageously have mathematically characteristic properties. They are preferably extreme values, zero points and/or points of inversion. In the example in Figure 4, the selected points K1..K7 on the signals f and f' which form the pattern signal are those for which the signal f or its derivative f' are at an extreme value or represent a zero point at one time.

According to the invention, the programmable arithmetic and logic unit RE illustrated in Figure 2 is assigned a processing state Z1..Zn to the fuzzy automatic-control device FA to each of the points K1..K7 selected by way of example in Figure 4, so that the fuzzy automatic-control device FA uses a sequence (formed in this way) of processing states Z1..Zn to define a measure for the probability that a measurement signal composed of the input variables u(t), u'(t) has a profile which corresponds to a pattern signal composed, by way of example, of the input variables f, f'. In relation to the state graphs illustrated in Figure 3, the programmable arithmetic and logic unit RE assigns a processing state Z1..Zn of the fuzzy automatic-control device FA to each of the seven selected points K1..K7. A first processing state Z1 is preferably used as a basic state in this case. With respect to the example of the pattern signal in Figure 4, which is composed of the signals f and f', this thus results in eight processing states Z1..Z8 of the fuzzy automatic-control device FA.

The fuzzy automatic-control device FA moves within the sequence of processing states Z1..Z8 which are illustrated in Figure 3. The processing states Z1..Z8 in this case correspond to the selected points K1..K7 of the signals f and f', which have already been recognized by the fuzzy automatic-control device FA. The higher a processing state Z1..Zn assumed by the fuzzy automatic-control device FA in this case, the greater is the level of probability that a measurement signal to be analyzed has a profile which corresponds to the pattern signal which is present in the form of the configuration PA of the fuzzy automatic-control device FA. If the fuzzy automatic-control device FA assumes the highest processing state Zn or Z8, then it has recognized in the measurement signal to be analyzed a profile which corresponds to the pattern signal.

Figure 5 shows the signals f and f' illustrated in Figure 4 in the form of a pattern signal T which is in the form of a trajectory. According to the invention, the pattern signal T is mapped by the programmable arithmetic and logic unit RE into an input value range M of the fuzzy automatic-control device FA. Furthermore, the programmable arithmetic and logic unit RE also maps the selected points K1..K7 and, according to the invention, generates so-called feature ranges M34, M53, M32, M23 in the input value range M, in such a manner that at least the selected points K1..K7 are located in these feature ranges M34, M53, M32, M23. In the example in Figure 5, the selected points K1..K7 are not shown in the form of points, but are bounded as feature ranges M33, M34, M53, M32, M23 illustrated by gray areas. In this example, the feature range M53 in this case indicates a maximum, and the feature range M23 indicates a minimum of the signal f, or a zero point of the signal f'.

Figure 6 once again shows the normalized input value range M from Figure 5. In order to improve the detection of the profile of the pattern signal T and including the feature ranges M33, M34, M53, M32, M23 which bound the selected points K1..K7, the programmable arithmetic and logic unit RE preferably generates further feature ranges M11..M65, which are illustrated by gray areas. Located between these areas in Figure 6 there are change regions which are bounded by gridlines and are illustrated by white areas, so that the normalized input value range M is completely covered by feature ranges M11..M65 and change regions. The programmable arithmetic and logic unit RE assigns to the feature ranges M11..M65, in particular, association functions f1..f6, f1'..f5' of the fuzzy logic device FZ illustrated in Figure 2. In this case, the feature ranges M11..M65 represent, in particular, the core region of the association functions f1..f6, f1'..f5', in which core region these functions have the value 1. The gridlines shown in Figure 6 are in each case located at the boundaries of the core regions of the association functions f1..f6, f1'..f5'. The individual association functions f1..f6, f1'..f5' merge linearly into one another in the edge regions so that their sum becomes, in particular, just unity. By way of example, the reference symbols f1..f6 and f1'..f5' are quoted here as linguistic variables, and are also used in the following text to indicate the coordinates of the feature ranges M11..M65.

By way of example, Figures 7a to 7h show diagrams which correspond to the Karnaugh maps from Boolean logic of the transformation criteria, produced according to the invention by the programmable arithmetic and logic unit RE, of the individual processing states Z1..Z8 of the fuzzy automatic-control device FA. According to the invention, the programmable arithmetic and logic unit RE for the configuration PA of the fuzzy automatic-control device FA in each case assigns a transformation criterion to each processing state Z1..Z8 for each feature range M11..M65 of the input value range M, which transformation criteria are shown in Figures 7a to 7h by the reference symbols Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn. The fuzzy automatic-control device FA executes this as a function of the current processing state Z1..Zn when the measurement signal u(t) and u'(t) to be analyzed passes through a feature range M11..M65, in order to change to a subsequent processing state Z1..Z8. When the fuzzy automatic-control device FA changes to a subsequent processing state Z1..Z8, the device thus changes from the current processing state Z1..Z8 to a higher or lower processing state Z1..Z8 or retains this processing state Z1..Z8.

With respect to the state graphs which are shown by way of example in Figure 3, Figures 7a to 7h show the transformation criteria for each processing state of the fuzzy automatic-control device FA, these transformation criteria having the change rules A1..A7, the stop rules B2..B7, the jump-back rules C3..C7 and the reset rules D1..D8. The numbers in the boxes denoted by the coordinates Z1..Z8, f1..f6, f1'..f5' in this case indicate the following processing state Z1..Z8 of the fuzzy automatic-control device FA resulting from the corresponding transformation criterion.

According to the invention, the fuzzy automatic-control device FA is configured by the programmable arithmetic and logic unit RE which, starting with the fuzzy automatic-control device FA in a first processing state Z1, defines the sequence of feature ranges M11..M65 which the pattern signal T must pass through along its profile. By way of example, Figures 7a to 7h in this case show the transformation criteria Z1..Z8, f1..f6, f1'..f5' for the respective operating states Z1..Z8 of the fuzzy automatic-control device FA. In particular, the programmable arithmetic and logic unit RE selects from the totality of feature ranges M11..M65 those feature ranges M23, M32, M33, M34, M53 in which a selected point K1..K7 of the pattern signal T is located. Furthermore, the feature range M33 is defined, in which the last selected point K7 of the pattern signal T is located, and the feature ranges M22, M24, M42, M44, in which no selected point K1..K7 of the pattern signal T is located.

In particular, all the transformation criteria for the processing states Z1..Z8 are initially defined by the programmable arithmetic and logic unit RE by means of reset rules D1..D8 such that the fuzzy automatic-control device FA jumps back to the first processing state Z1. This means that, subsequently, the fuzzy automatic-control device FA is reset to the initial state Z1 again in the event of any discrepancy between a measurement signal u(t), u'(t) to be analyzed and the pattern signal T.

If a selected point K1..K7 is located in a feature range M11..M65 defined along the profile of the pattern signal T, the programmable arithmetic and logic unit RE defines the corresponding transformation criterion for the current processing state such that the fuzzy automatic-control device FA changes to the next-higher processing state Zk+1. The corresponding transformation criterion for the next-higher processing state is defined such that the fuzzy automatic-control device FA remains in the next-higher processing state, and the corresponding transformation criterion for the next but one processing state is defined such that the fuzzy automatic-control device FA jumps back to the next-higher processing state. In order to define further transformation criteria, the programmable arithmetic and logic unit RE uses the next-higher processing state of the fuzzy automatic-control device FA as the new current processing state.

With respect to the example illustrated in Figure 7a, the fuzzy automatic-control device FA is initially in the processing state Z1. When the programmable arithmetic and logic device RE recognizes the first selected point K1 in the field f3/f3' in the measurement signal to be analyzed, the processing state of the fuzzy automatic-control device FA is intended to change to the next-higher processing state Z2. The transformation criterion in the field f3/f3' of the first processing state Z1 therefore uses the change rule A1 to change the fuzzy automatic-control device FA to the next-higher, second processing state Z2. In the next-higher, second processing state Z2, the transformation criterion in the field f3/f3' uses the stop rule B2 to ensure that the fuzzy automatic-control device FA remains in this next-higher, second processing state Z2. In the second-higher, third processing state Z3, the transformation criterion in the field f3/f3' uses the jump-back rule C3 to cause the fuzzy automatic-control device FA to jump back to the second processing state Z2.

If the last selected point K7 is located in a feature range M11..M65 defined along the profile of the pattern signal T, the programmable arithmetic and logic unit RE defines the corresponding transformation criterion A7 for the current processing state Z7 such that the fuzzy automatic-control device FA changes to the next-higher processing state Z8. All the transformation criteria for the next-higher processing state Z8 have already been defined by means of reset rules D8, in particular, such that the fuzzy automatic-control device FA jumps back to the first processing state Z1.

If no selected point K1..K7 is located in a feature range M11..M65 defined along the profile of the pattern signal T, the programmable arithmetic and logic unit RE defines the corresponding transformation criterion for the current processing state such that the fuzzy automatic-control device remains in the current processing state. The corresponding transformation criterion for the next-higher processing state is defined such that the fuzzy automatic-control device jumps back to the current processing state.

In the example in Figure 7c, the profile of the pattern signal T in the third processing state Z3 intersects a feature range which is represented by the field f4/f4' without any selected point K1..K7 of the pattern signal T being located there. The transformation criterion in the field f4/f4' of the third processing state Z3 therefore uses the stop rule B3 to ensure that the fuzzy automatic-control device FA remains in the current, third processing state Z3. In the next-higher, fourth processing state Z4, the transformation criterion in the field f4/f4' uses the jump-back rule C4 to cause the fuzzy automatic-control device FA to jump back to the third processing state Z3.

In the situation when two successive feature ranges M11..M65 are arranged diagonally with respect to one another in the sequence of the feature ranges M11..M65 through which the pattern signal T passes in the input value range M, the programmable arithmetic and logic unit RE advantageously defines at least the corresponding transformation criteria for those feature ranges M11..M65 in the current processing state which are located in between these ranges and to the side of them, such that the fuzzy automatic-control device FA remains in the current processing state. These are, in particular, the feature ranges M11..M65, which are located in the area of a rectangle which is covered by the two successive feature ranges M11..M65, which are arranged diagonally with respect to one another as corner regions. In the next-higher processing state, the corresponding transformation criteria are defined such that the fuzzy automatic-control device jumps back to the current processing state.

In the example in Figure 7c, the fields f4/f4' and f5/f3' are diagonal with respect to one another, which means that the transformation criterion in the field f5/f3' causes the fuzzy automatic-control device FA to change to the next-higher, fourth operating state Z4. The transformation criteria for the fields f4/f3' and f5/f4' which are located in between them and to the side of them use the stop rules B3 to ensure that the fuzzy automatic-control device FA remains in the current, third processing state.

In an advantageous embodiment of the method according to the invention, this method is used in a device for early break-out recognition in continuous casting plant. In this case, the pattern signal T includes at least the profile of a temperature signal which leads to break-out of the cast strand. The measurement signal u(t), u'(t) to be analyzed in this case includes at least the actual value of the temperature of the cast strand.

One advantage of the method for using a programmable arithmetic and logic unit for configuring a fuzzy automatic-control device which is used for comparing a measurement signal with a pattern signal is that transformation criteria for configuring the fuzzy automatic-control device are produced fully automatically by the arithmetic and logic unit. Even if the pattern signals change frequently, the fuzzy automatic-control device can thus be reconfigured quickly, without complications and flexibly.

Patent Claims

1. A method for configuring (PA) a fuzzy automatic-control device (FA) which is used for comparing a measurement signal (u(t), u'(t)) with a pattern signal (T, f, f') by means of a programmable arithmetic and logic unit (RE) which

a) selects points (K1..K7) in the profile of the pattern signal (T, f, f'),

b) images the pattern signal (T, f, f') into an input value range (M) of the fuzzy automatic-control device (FA),

c) generates feature ranges ((M11..M65) in the input value range (M) in such a manner that at least the selected points (K1..K7) are located in these feature regions,

d) assigns a processing state (Z1..Zn) of the fuzzy automatic-control device (FA) to each selected point (K1..K7), such that the fuzzy automatic-control device (FA) uses a sequence, formed in this way, of processing states (Z1..Zn) to define a measure that the measurement signal (u(t), u'(t) has a profile corresponding to that of the pattern signal (T, f, f'),

e) for configuring (PA) the fuzzy automatic-control device (FA), a transformation criterion (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) is in each case assigned to each processing state (Z1..Zn) for each feature range (M11..M65) of the input value range (M), which transformation criterion the fuzzy automatic-control device (FA) executes as a function of its current processing state (Z1..Zn) when the measurement signal (u(t), u'(t)) to be analyzed passes through a feature range (M11..M65) in order to change to a subsequent processing state (Z1..Zn).

2. The method as claimed in claim 1, wherein, starting from a first processing state (Z1) of the fuzzy automatic-control device (FA), the programmable arithmetic and logic unit (RE) defines, along the profile of the pattern signal (T, f, f') the sequence of feature ranges

(M11..M65) which the pattern signal (T, f, f') passes through and, from this,

a) selects the feature ranges (M23, M32, M33, M34, M53) in which a selected point (K1..K7) of the pattern signal (T, f, f') is located, and

b) selects the feature range (M33) in which the last selected point (K7) of the pattern signal (T, f, f') is located.

3. The method as claimed in claim 2, wherein the programmable arithmetic and logic unit (RE) initially defines the transformation criteria (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) for the processing states (Z1..Zn) such that the fuzzy automatic-control device (FA) jumps back to the first processing state (Z1).

4. The method as claimed in claim 3, wherein, in the situation when a selected point (K1..K7) of the pattern signal (T, f, f') is located in a selected feature range (M23, M32, M33, M34, M53), the programmable arithmetic and logic unit (RE)

a) defines the corresponding transformation criterion (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) of the current processing state (Zk) such that the fuzzy automatic-control device (FA) changes to the next-higher processing state (Zk+1),

b) defines the corresponding transformation criterion (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) of the next-higher processing state (Zk+1) such that the fuzzy automatic-control device (FA) remains in the next-higher processing state (Zk+1),

c) defines the corresponding transformation criterion (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) of the next but one processing state (Zk+2) such that the fuzzy automatic-control device (FA) jumps back to the next-higher processing state (Zk+1), and

d) uses the next-higher processing state (Zk+1) of the fuzzy automatic-control device (FA) as the new current processing state for defining further transformation criteria (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn).

5. The method as claimed in one of claims 3 or 4, wherein, in the situation when the last selected point (K7) of the pattern signal (T, f, f') is located in a selected feature range (M33), the programmable arithmetic and logic unit (RE)

a) defines the corresponding transformation criterion (Z7, f1..f6, f1'..f5', A7, B7, C7, D7) for the current processing state (Z7) such that the fuzzy automatic-control device (FA) changes to the next-higher processing state (Z8), and

b) defines all the transformation criteria (Z8, f1..f6, f1'..f5', D8) for the next-higher processing state (Z8) such that the fuzzy automatic-control device (FA) jumps back to the first processing state (Z1).

6. Method as claimed in one of claims 3 to 5, wherein, in the case when no selected point (K1..K7) of the pattern signal (T, f, f') is located in a selected feature range (M22, M24, M42, M44), the programmable arithmetic and logic unit (RE)

a) defines the corresponding transformation criterion (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) for the current processing state (Zk) such that the fuzzy automatic-control device (FA) remains in the current processing state (Zk), and

b) defines the corresponding transformation criterion (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) for the next-higher processing state (Zk+1) such that the fuzzy automatic-control device (FA) jumps back to the current processing state (Zk).

7. The method as claimed in one of claims 3 to 6, wherein, in the situation when two successive feature ranges (M11..M65) are arranged diagonally with respect to one another in the sequence of the feature ranges (M11..M65) through which the pattern signal (T, f, f') passes in the input value range (M), the programmable arithmetic and logic unit (RE) at least defines the corresponding transformation criteria (Z1..Z8, f1..f6, f1'..f5', A1..An-1, B2..Bn-1, C3..Cn-1, D1..Dn) of those feature ranges (M11..M65) which are located in between these ranges in the input value range (M) and at the side

a) in the current processing state (Zk) such that the fuzzy automatic-control device (FA) remains in the current processing state (ZK), and

b) in the next-higher processing state (Zk+1) such that the fuzzy automatic-control device (FA) jumps back to the current processing state (Zk).

8. The method as claimed in one of the preceding claims, wherein the programmable arithmetic and logic unit (RE) assigns the feature ranges (M11..M65) in the input value range (M) association functions (f1..f6, f1'..f5') of the fuzzy automatic-control device (FA).

9. The method as claimed in one of the preceding claims, wherein the pattern signal (T, f, f') has a signal profile (f) and at least one mathematical derivative (f') of the signal profile (f), in particular a time derivative.

10. The method as claimed in one of the preceding claims, wherein the programmable arithmetic and logic unit (RE) defines the selected points (K1..K7) in such a manner that they are characteristic of the profile of the pattern signal (T, f, f').

11. A use of the method as claimed in one of the preceding claims in a device for early break-out recognition in continuous casting plants, wherein

a) the pattern signal (T, f, f') includes at least the time profile of a temperature signal which leads to break-out of the cast strand, and

b) the measurement signal (u(t), u'(t)) includes at least the actual value of the temperature of the cast strand.

List of reference symbols

MA	**Fuzzy automatic-control device**, fundamental design
F, G	First and second function elements of the fuzzy automatic-control device
MZ	Memory element for storing the internal state z(i) of the fuzzy automatic-control device
u(i)	Input vector at the time i
z(i)	Buffer-stored internal state vector
y(i)	Output vector
FA	**Fuzzy automatic-control device** for pattern recognition
FZ	Fuzzy logic
MZ	Memory element for storing the state z(i) of the fuzzy automatic-control device
PA	Configuration of the fuzzy automatic-control device for recognizing a specific signal profile, that is to say pattern, of the input variables f and f'
u(t)	Normalized input signal
u'(t)	Normalized derivative with respect to time of the input signal
P(i+1)	**Recognition level** of the signal profile, defined by the configuration PA, in the input variables f and f' as a percentage from 0 to 100%, that is to say the probability that a specific signal profile of the input variables f and f' is present.
P(i)	Internal state vector

Fuzzy state graph for the fuzzy automatic-control device

Z1..Zn	**Recognition states** of the fuzzy automatic-control device in the form of linguistic values of the recognition probability P(i)
A1..An-1	**Change rules** for the fuzzy automatic-control device to change to the next-higher operating state
B2..Bn-1	**Stop rules** for the fuzzy automatic-control device to remain in the previous operating state
C3..Cn-1	**Jump-back rules** for the fuzzy automatic-control device to jump to the next-lower operating state
D1..Dn	**Reset rules** for resetting the fuzzy automatic-control device to operating state Z1
T	**Pattern signal**, x-y representation of the signals f and f' in the form of a trajectory
f, f'	Signal f, forming the pattern signal, and its derivative f' with respect to time
K1..K7	**Selected points** in the profile of the pattern signal f to be recognized by the fuzzy automatic-control device, and its derivative f'
f1..f5	Association functions for the signal f for the fuzzy logic FZ of the fuzzy automatic-control device FA, in the form of linguistic values
f1'..f5'	Association functions for the derivative f' of the pattern signal
M11..M65	**Features** in the form of feature ranges which are illustrated in gray and can be adopted by the trajectory

Karnaugh maps of the control basis

A1..A7	Change rules
B2..B7	Stop rules
C3..C7	Jump-back rules
D1..D8	Reset rules

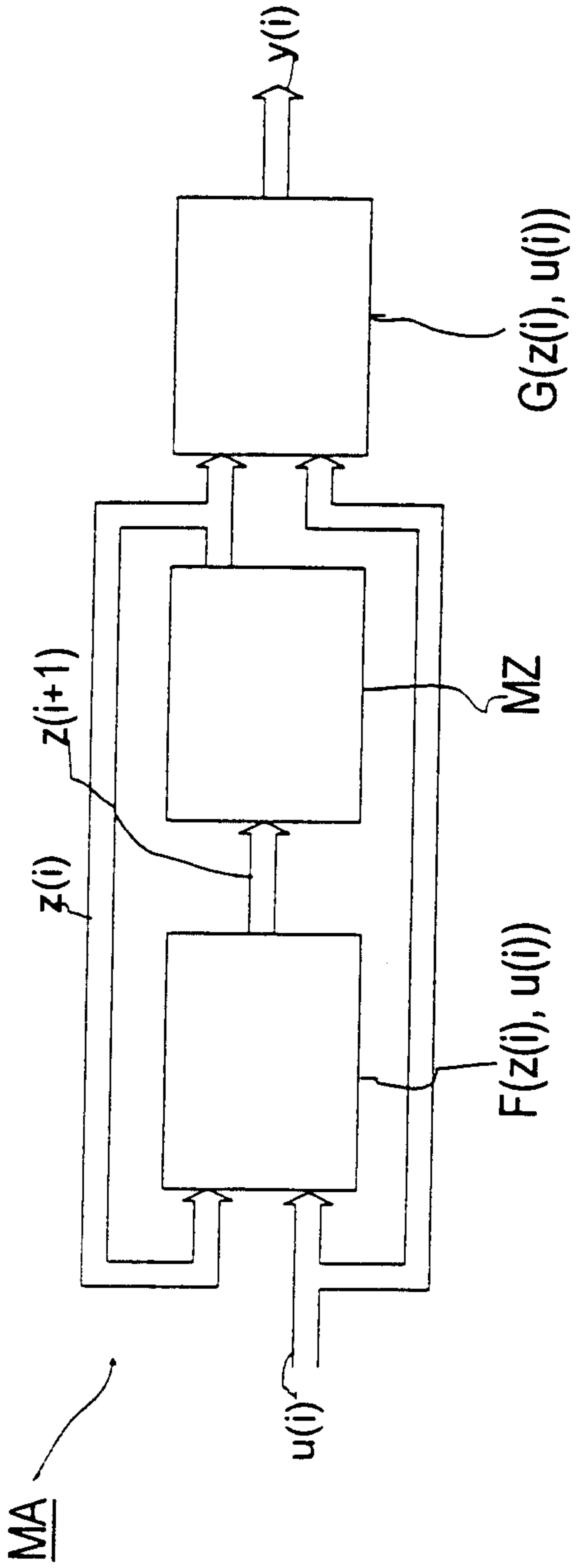


FIG 1

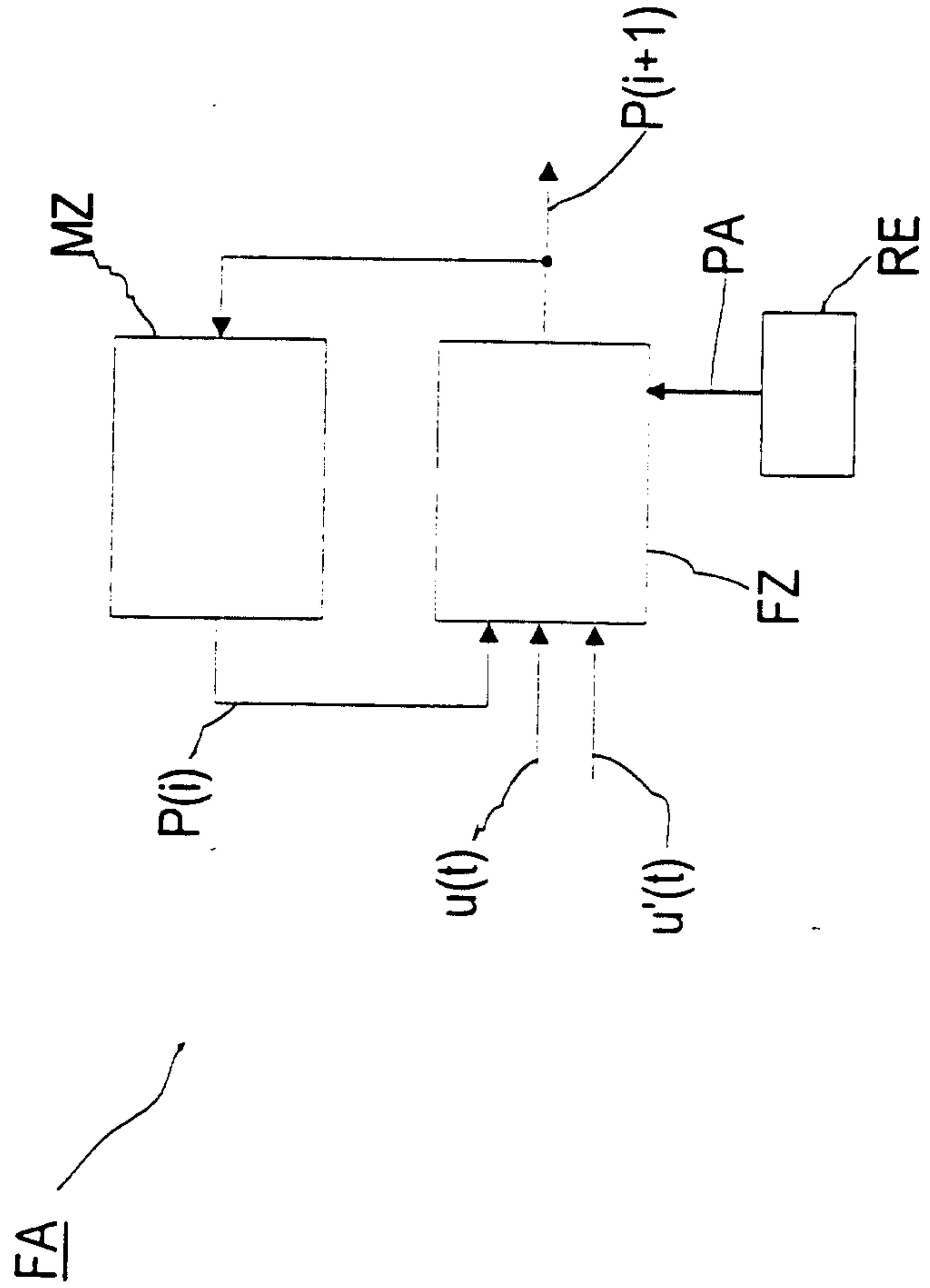


FIG 2

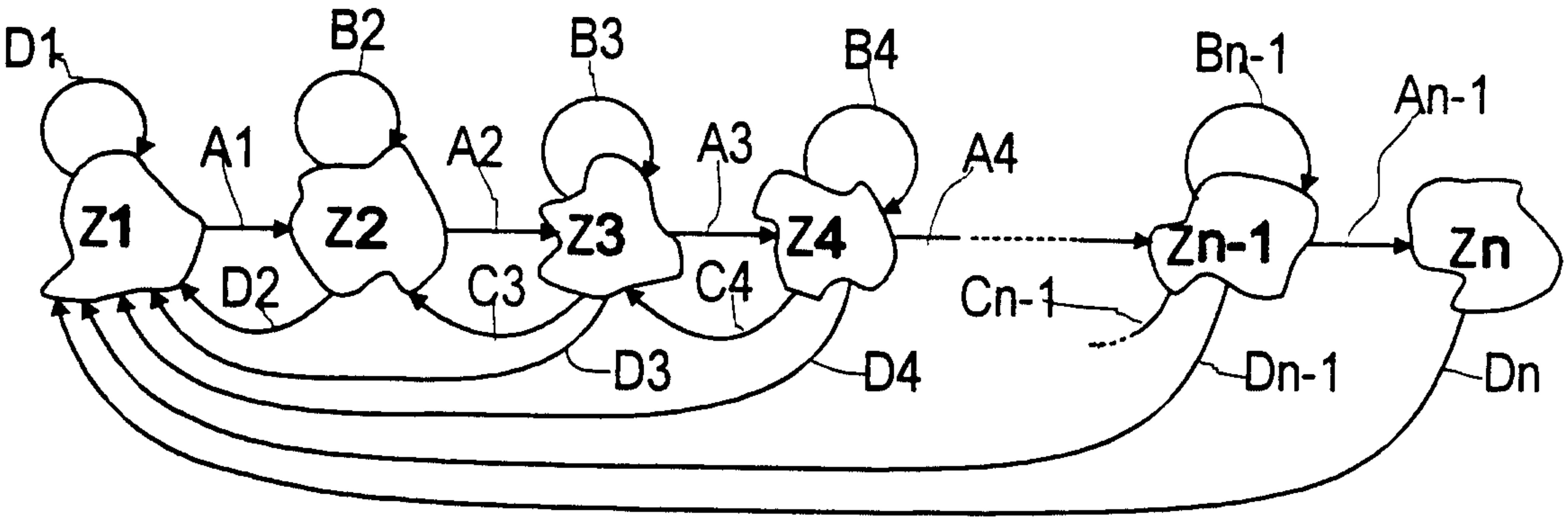

D1
B2
B3
B4
Bn-1
An-1
A1
A2
A3
A4
Z1
Z2
Z3
Z4
Zn-1
Zn
D2
C3
C4
Cn-1
D3
D4
Dn-1
Dn

FIG 3

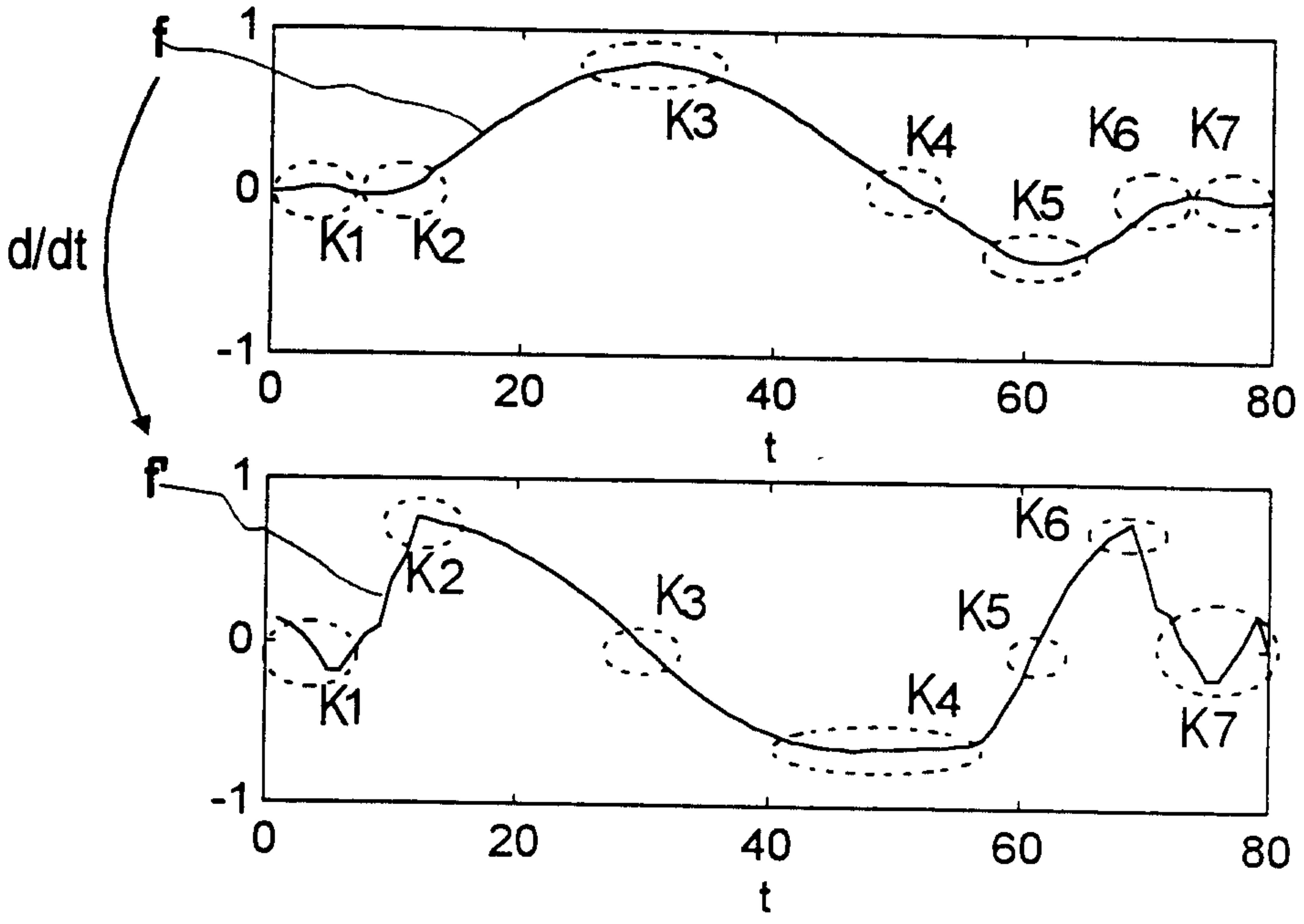

f
d/dt
f'
1
0
-1
0
20
40
60
80
t
K1
K2
K3
K4
K5
K6
K7

FIG 4

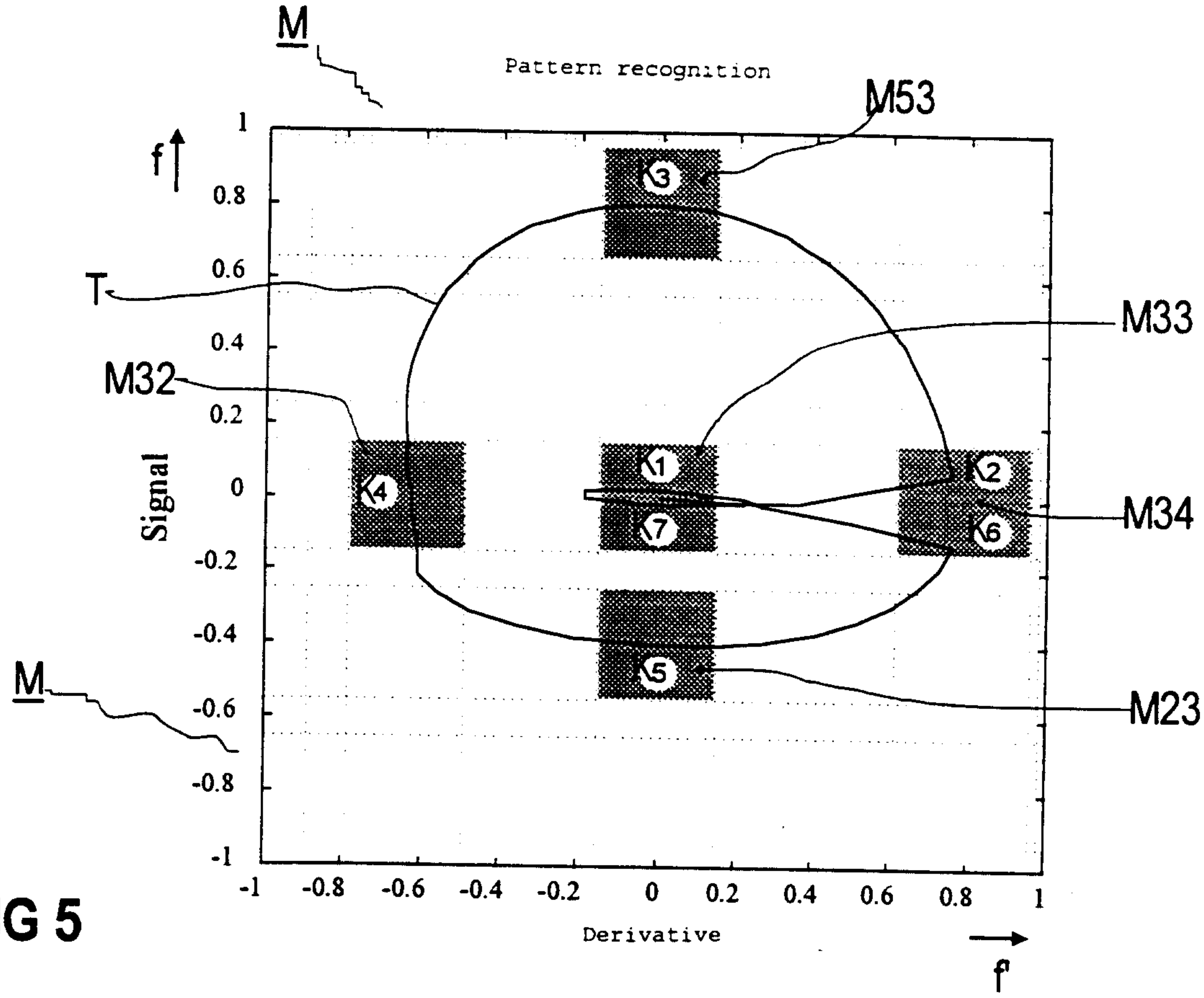

M
Pattern recognition
M53
f
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
T
M33
M32
Signal
K1
K2
K3
K4
K5
K6
K7
M34
M23
M
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Derivative
f'

FIG 5

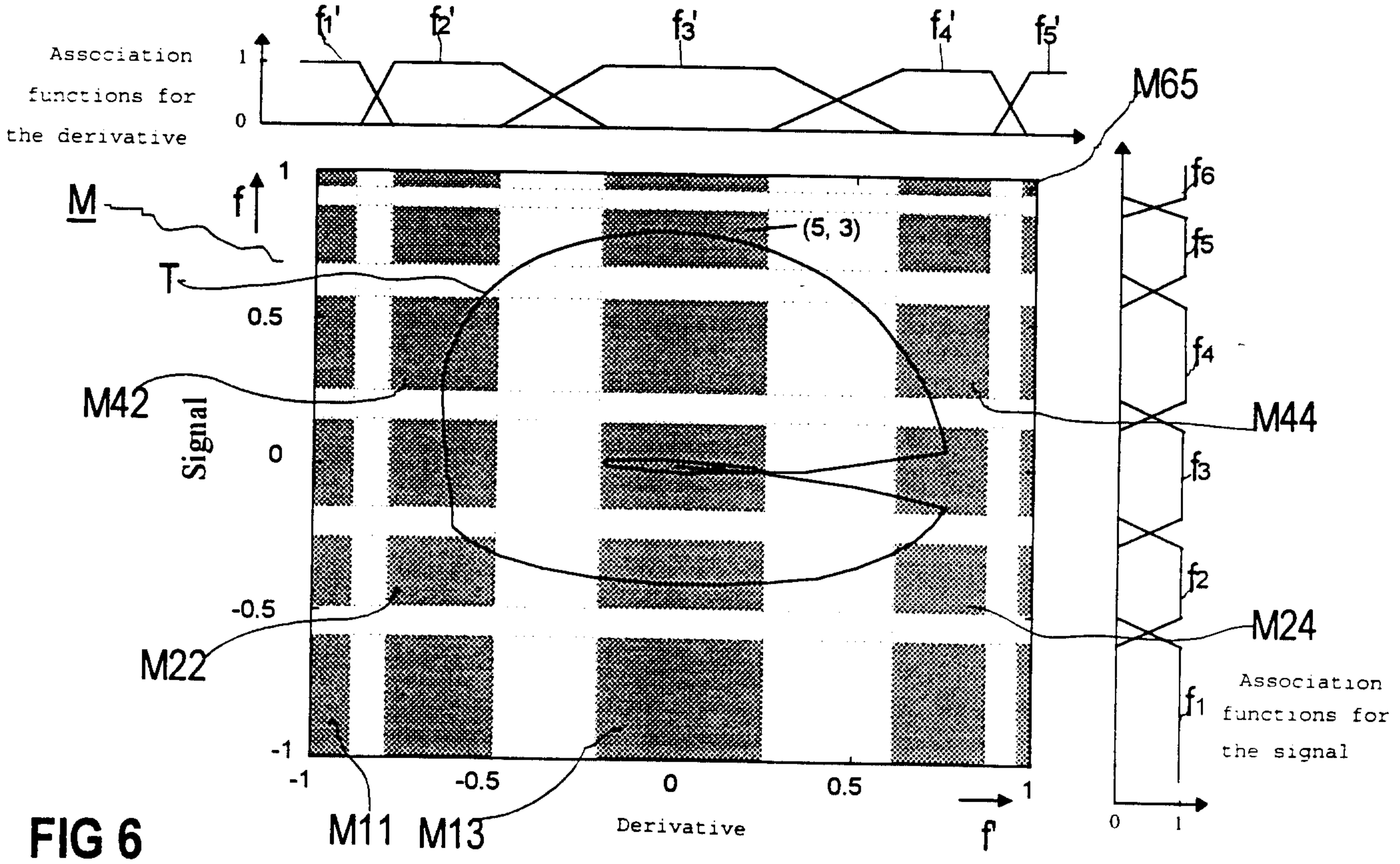

f1'
f2'
f3'
f4'
f5'
Association functions for the derivative
1
0
M65
M
f
1
(5, 3)
T
0.5
M42
Signal
0
M44
-0.5
M22
M24
-1
-1
-0.5
0
0.5
1
Derivative
f'
M11
M13
f6
f5
f4
f3
f2
f1
Association functions for the signal
0
1

FIG 6

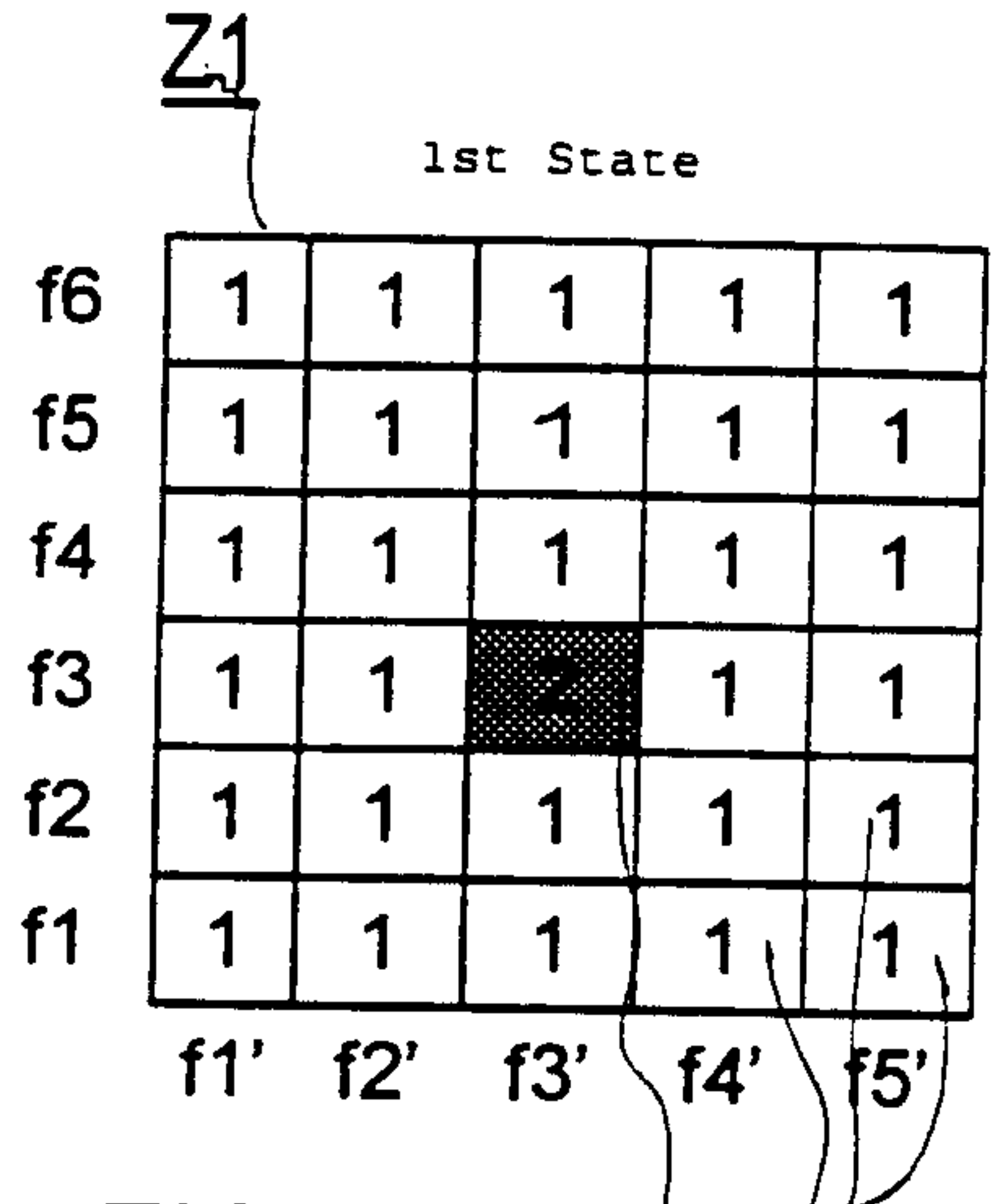


FIG 7a

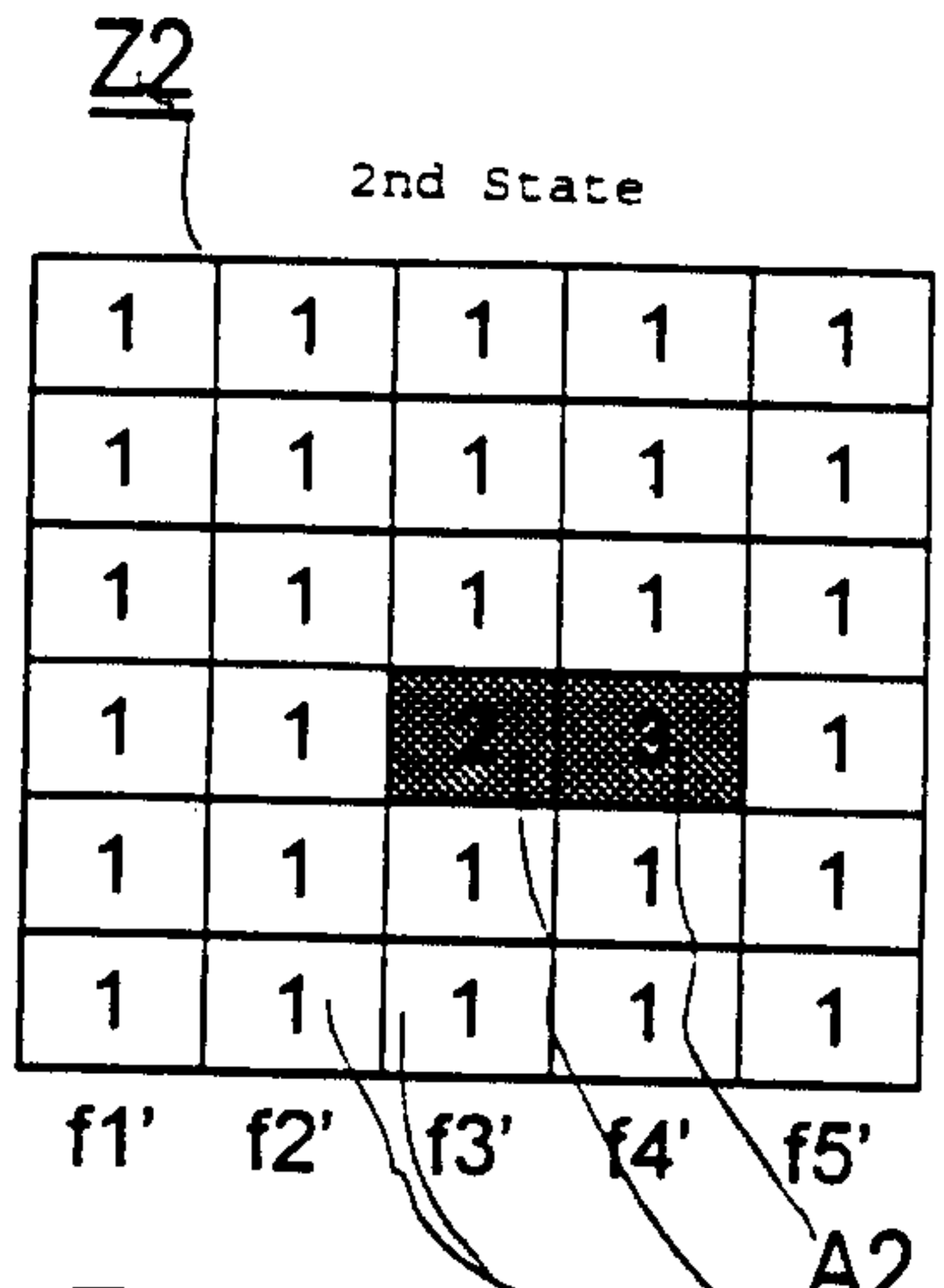


FIG 7b

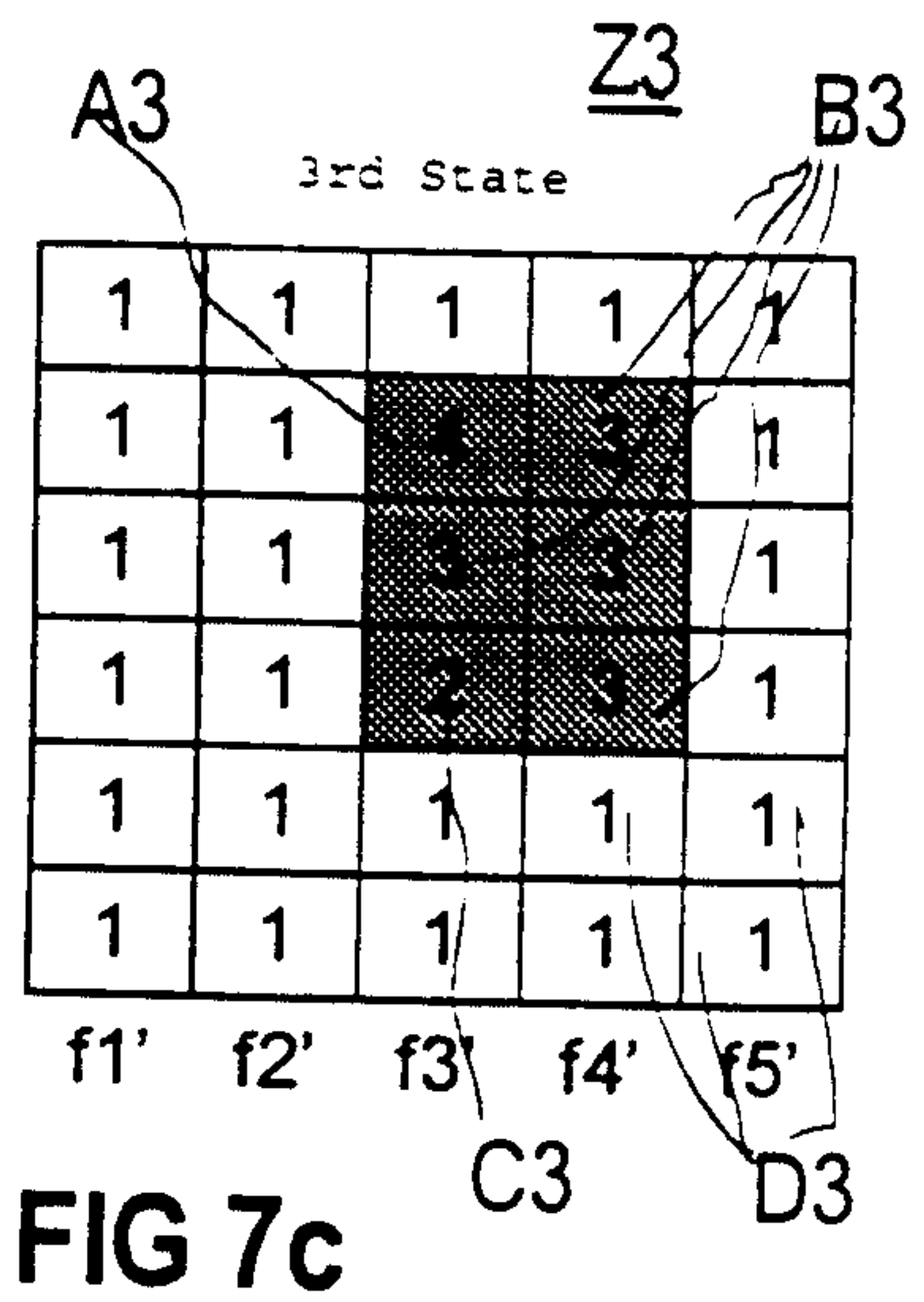


FIG 7c

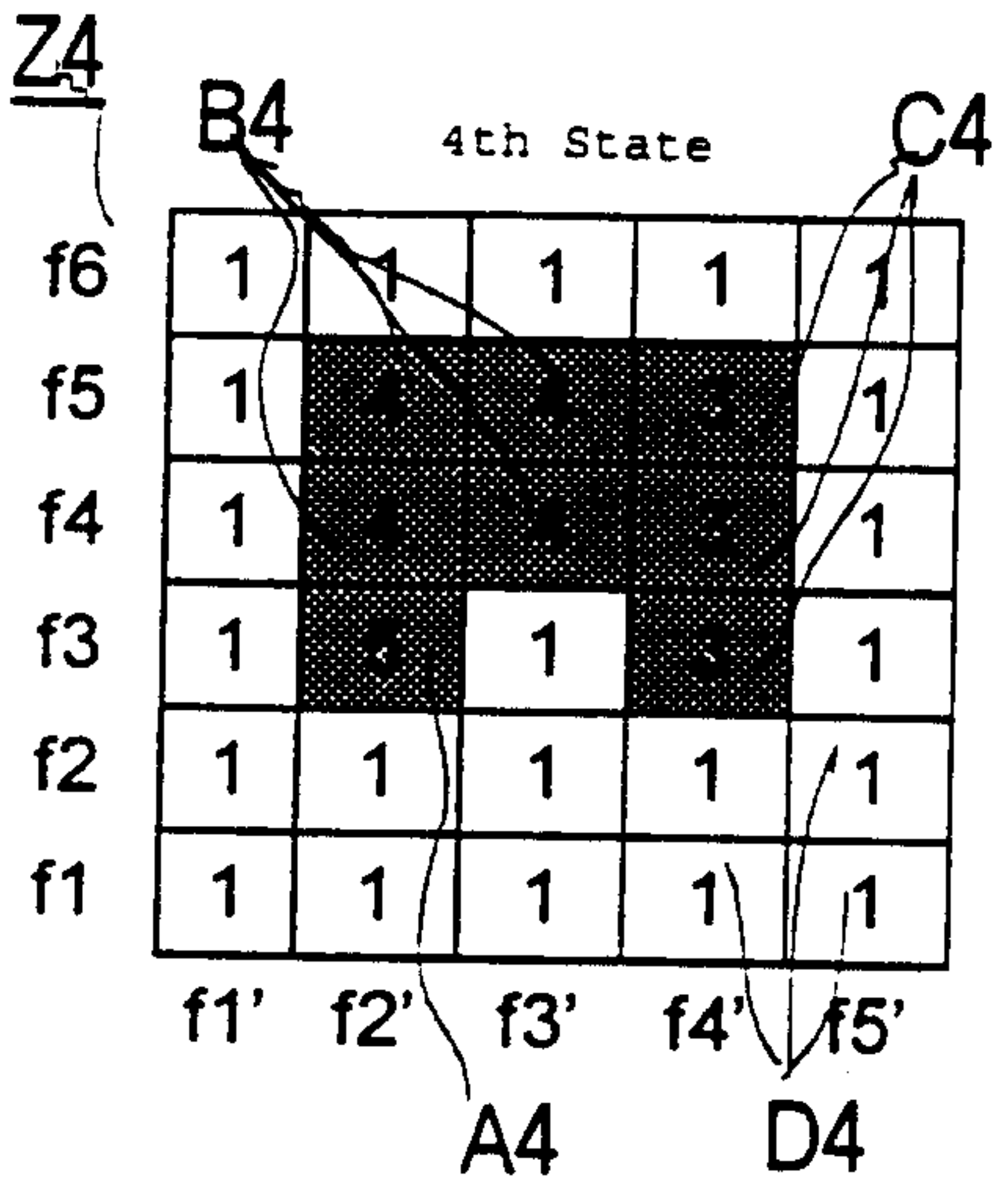


FIG 7d

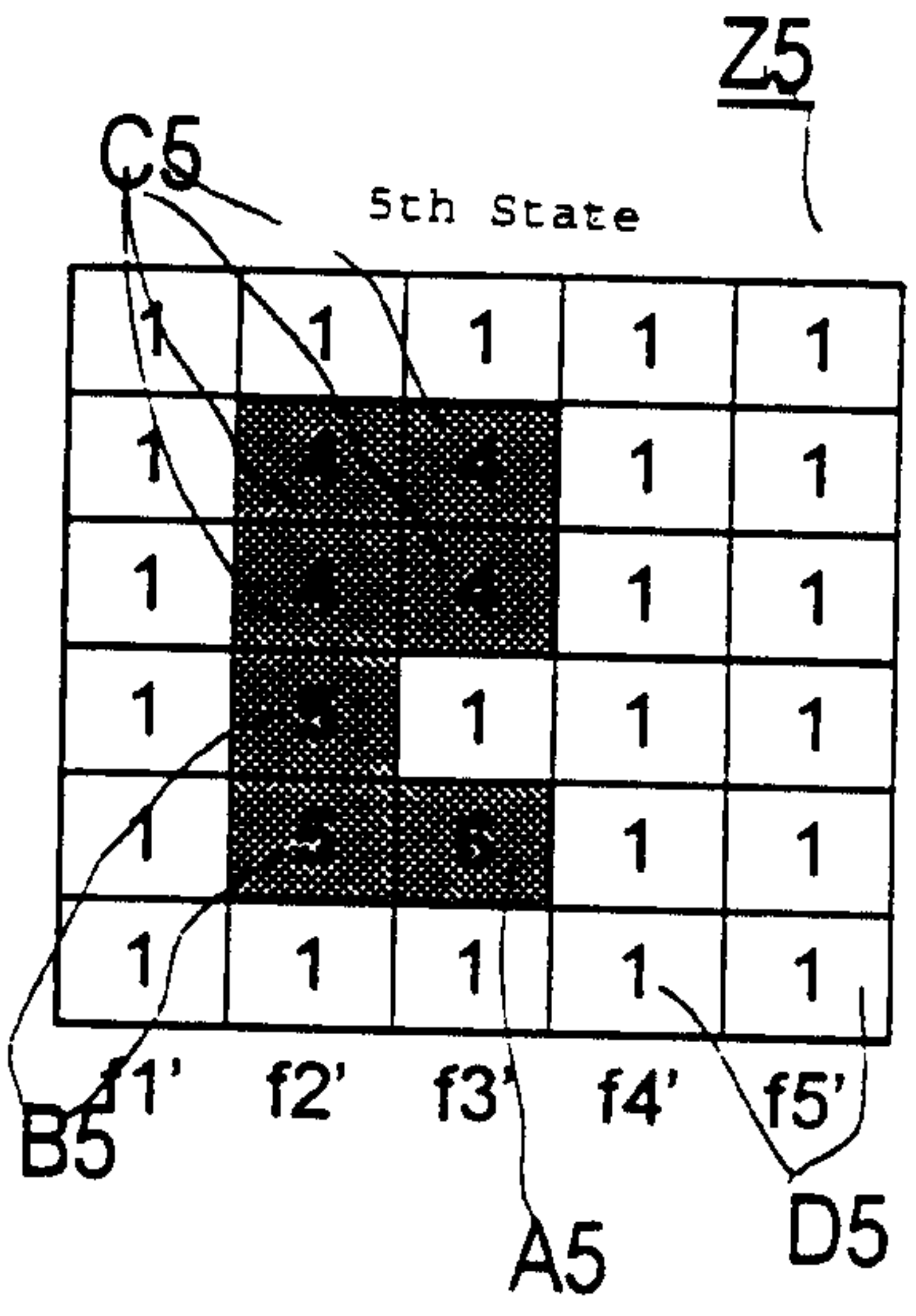


FIG 7e

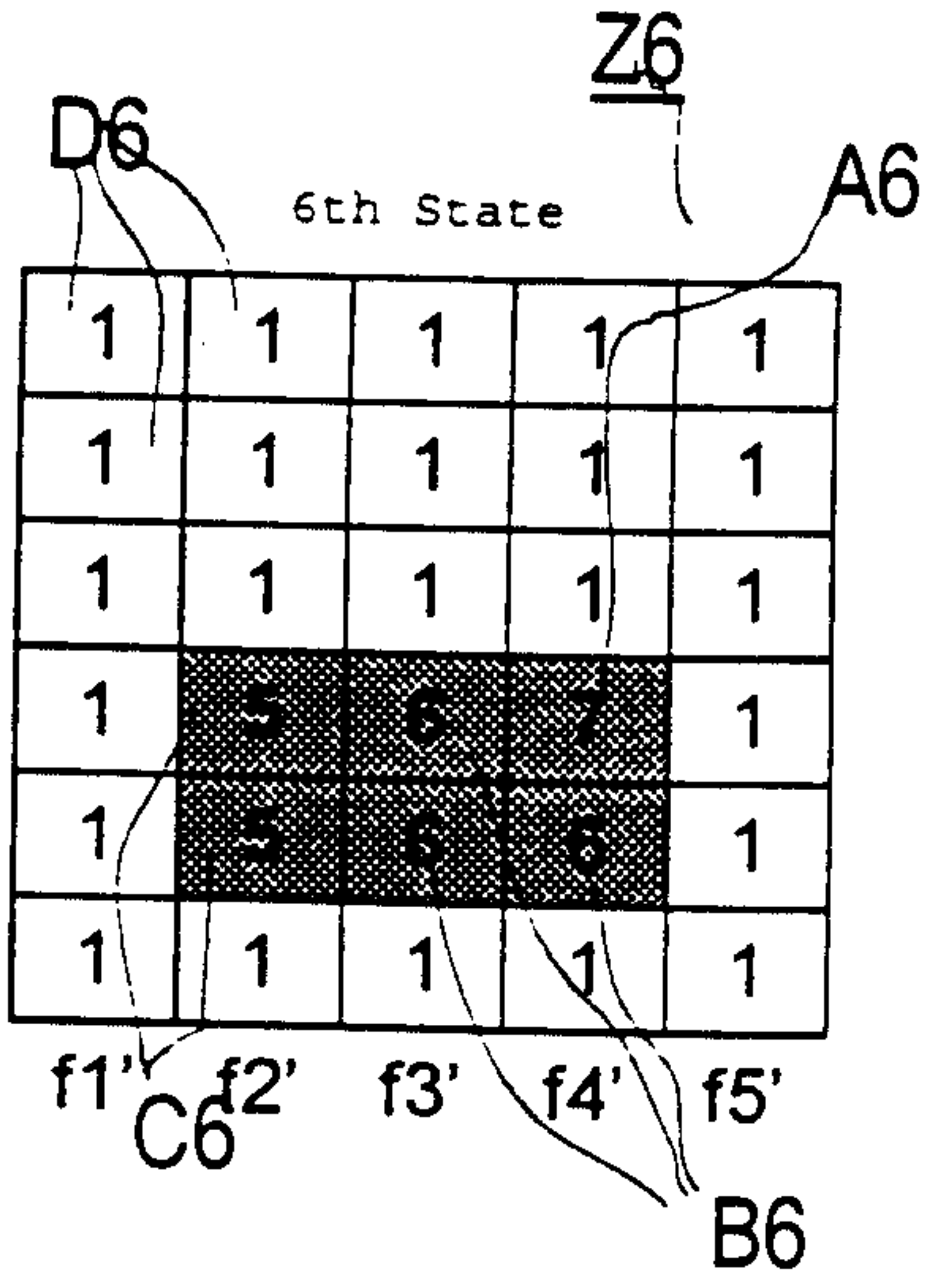


FIG 7f

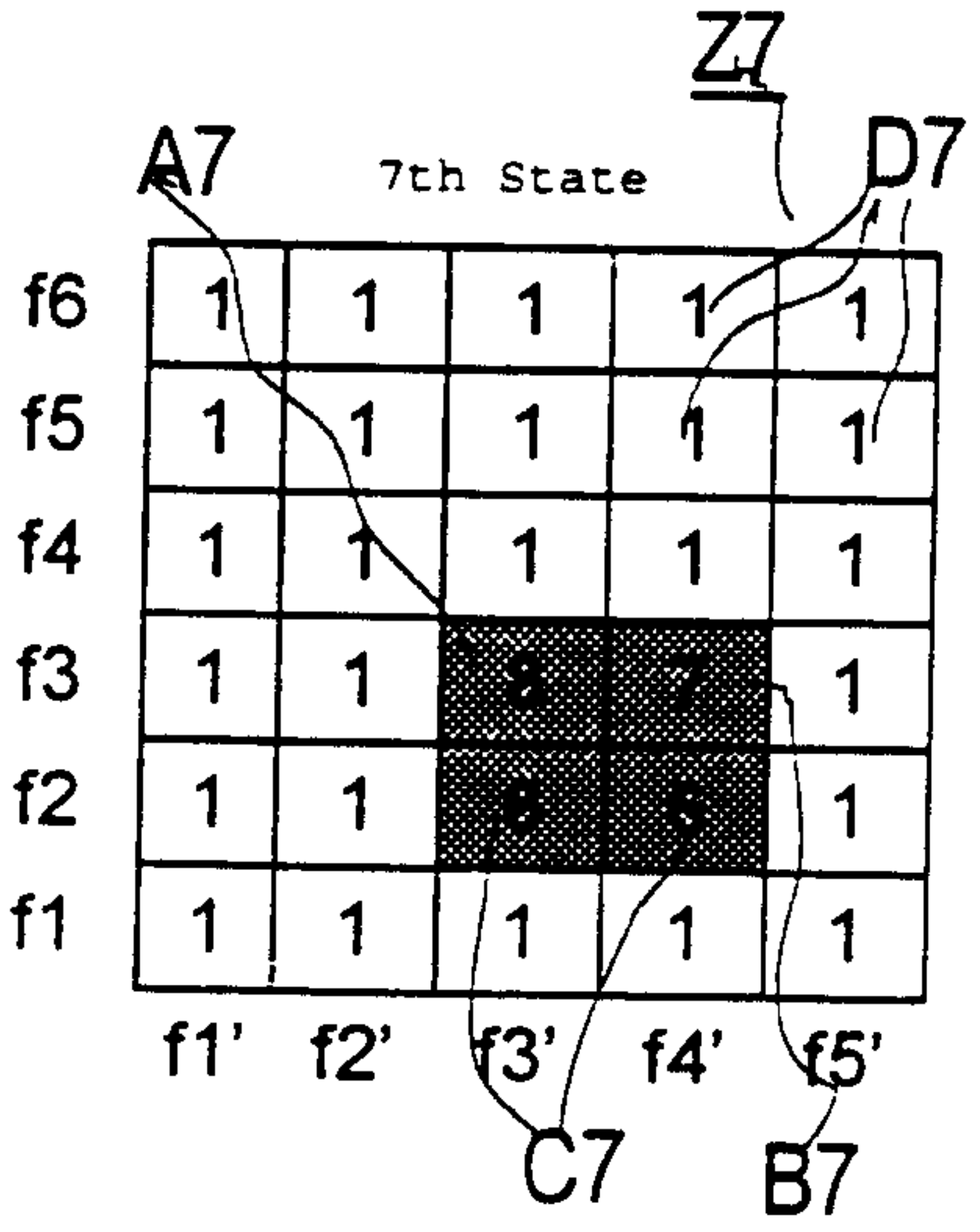


FIG 7g

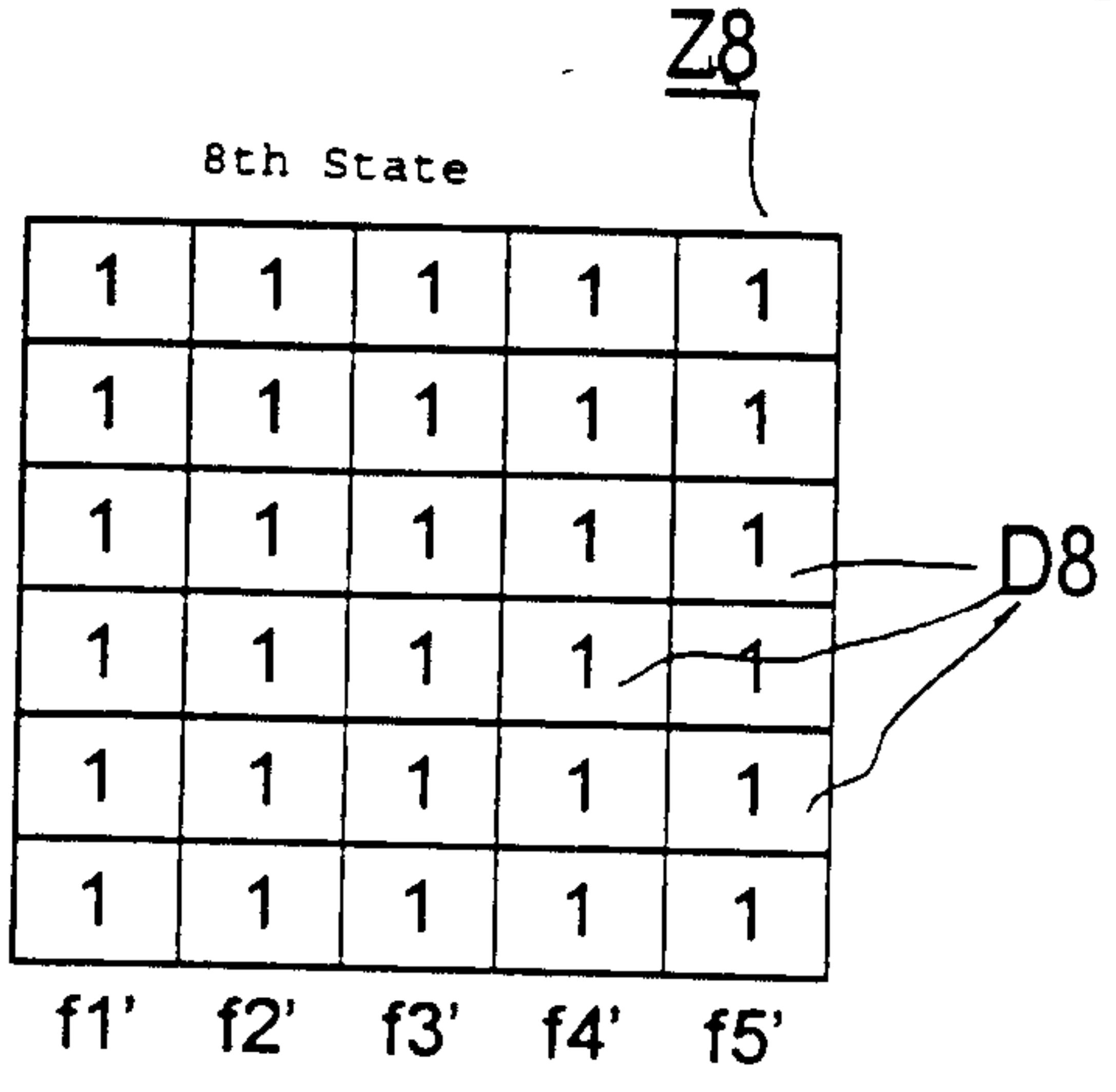


FIG 7h