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(71) Applicant: **INVENTIO AG**
Seestrasse 55
CH-6052 Hergiswil NW (CH)

(72) Inventor: **Shah, Denis D.**
605 Golf Terrase
Union, NJ 07083 (US)
Inventor: **Gerhardson, Richard D.**
44 Center Grove Road A19
Randolph, NJ 07869 (US)
Inventor: **Chou, Edward L.**
148 McIntosh Drive
Mahwah, NJ 07430 (US)

(54) Intelligent distributed control for elevators.

(57) Distributed processing units (DPU) are applied to elevator dispatching and back-up architecture. They are localizing the processing functions by sensing and controlling local devices and serially transmitting up-dates to other DPUs via one or more communication media (18). This makes it possible to confine the wiring to local levels eliminating the need for a centralized processor.

The distributed processing units (DPU) are designed as floor processing units (FPUa,FPUb,...) one on each floor (E1...), car processing units (CPUa,CPUb,...) in each car (2), group processing units (GPUa,GPUb,...) and signalling processing units (SPUa,SPUb,...) in the machine room (22). They all possess intelligence to communicate and to perform local control algorithms.

The distributed control is structured as a neural network, the nodes being implemented by the distributed processing units (DPU). Depending on the function to be processed, there are main nodes (A0,B0,C0...) with additional back-up nodes (Aa,Ba,Ca...) and auxiliary nodes (A1,A2,A3...).

The inventive, distributed control is characterized by modularity, configurability and simplicity, providing reduced development cycle, ease of maintenance and increased reliability.

EP 0 663 366 A1

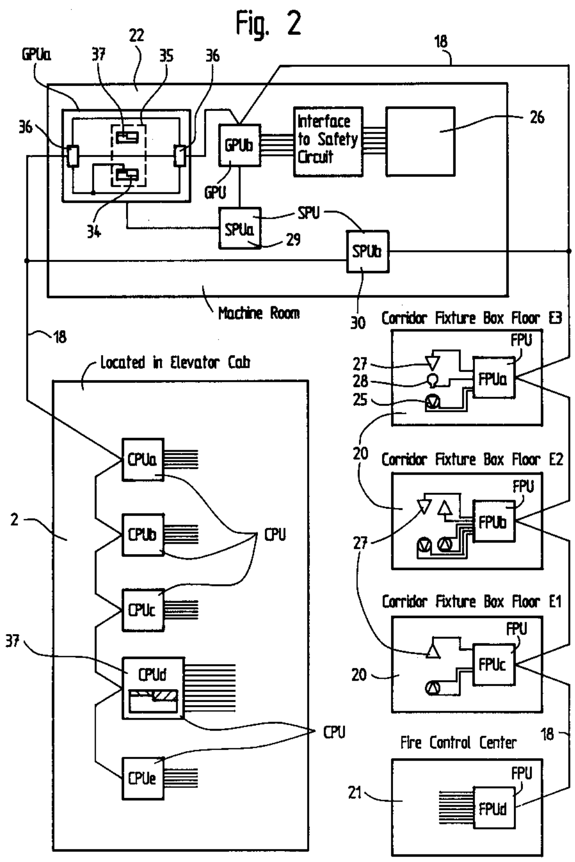


Fig. 2
GPUa
37
22
35
36
18
36
GPUb
Interface to Safety Circuit
26
GPU
SPU
34
SPUa
29
SPUb
Machine Room
30
Corridor Fixture Box Floor E3
FPU
18
Located in Elevator Cab
27
28
25
FPUa
CPUa
20
Corridor Fixture Box Floor E2
FPU
2
CPUb
CPU
FPUb
27
CPUc
Corridor Fixture Box Floor E1
FPU
37
CPUd
FPUc
20
CPU
Fire Control Center
18
FPU
CPUe
21
FPUd

The present invention relates to a new and improved intelligent distributed control for elevators, comprising a plurality of elevators arranged in conventional manner for servicing a plurality of floors of a building, including a group controller, with hall call registering devices disposed at each of the floors to originate hall calls for up and down service at each of said floors, for exchanging signals with each of said elevators and for controlling the operation of said elevators in response to said hall calls and in response to signals received from said elevators, further including for each of said elevators a car with car calls registering devices for service required by passengers therein, a car drive for providing and arresting the motion of said car, and a car controller for providing signals indicative of conditions of said car, for controlling said car motion means to cause said car to move in a selected up or down direction and to stop in response to said signals indicative of conditions of said car and to signals received from said group controller means whereby
said group controller means comprises a signal processor means responsive to said signals indicative of conditions of each of said cars for providing for each car, upon generation of a hall call an evaluation calculation and an optimum elevator car is selected on the basis of an evaluation calculation result and dispatched to answer said hall call,

Traditionally, an elevator controller has been a centralized system, in which the operations are controlled by one intelligent station in the system. This station may be located in the machine room, inside or on top of the cab etc.

Thus, such a control has become known from the US Patent No 5,305,198 issued 19.04.1994 (IP 389) assigned to the same assignee as the present application. In this system target calls are allocated definitively and immediately to the individual elevators for serving the call according to higher rank and lower rank function requirements. These allocations are indicated immediately at the call input floors. A weighted sum corresponding to higher rank function requirements is formed from partial operating costs, this is modified into operating costs in the sense of lower rank function requirements by means of variable bonus and penalty point factors and a target call is allocated to the elevator with the lowest operating costs. This method is implemented in an industrial computer by means of a target call allocation algorithm with subordinate algorithms for the bonus and penalty point tracking and the costs computation. This computation of the operating costs takes place in the costs computation algorithm according to a special costs formula, wherein the readjusted bonus and penalty point factors act multiplicatively on a six term partial costs sum. The prior art uses a computer as a centralized control for an elevator group of three elevators A,B,C and is operated without car calls but exclusively by target calls. The different elements of the elevator group are connected to the controlling computer by a bus system: The measuring and adjusting elements by a elevator bus, the elements in each car by a car bus and the decade keyboards on the floors to enter target calls by a floor bus. The elevator bus, the car bus and the floor bus form a threefold bus system which is connected to the computer by a special interface. The centralized computer can be of any suitable configuration such as a separate computer for each elevator car with one of the computers also controlling the group functions, a single computer for the whole elevator group or a single computer for two or more elevator groups. Common to all these computer configurations is a more or less centralized control.

A major disadvantage of this type of system configuration is that despite the use of a bus system substantial wiring effort is required. Wiring from distant locations in the system to a centralized location must be done. Not only is this process expensive, but it can also be error prone and tedious. Another disadvantage of such a system is that it requires enormous efforts for software development, testing and maintenance. When the elevator system is increased, i.e., when the numbers of floors and cars are increased the centralized computer and other elevator control apparatuses may be overloaded. In this case, the load is unbalanced and the computer processing efficiency for the total system is poor. With a single centralized station for elevator control there is no possibility for distributing and averaging the load of control functions and data processing.

Accordingly, it is the task of the present invention to overcome the above mentioned disadvantages by providing a completely modular system with greatly reduced overall wiring effort. In addition, the control according to the invention shall be so structured to display increased system efficiency and reliabilty for all functions relating to bank service. This problem is solved according to the invention by the means as characterized in the version of the independent claim. Advantageous developments are indicated in the dependent claims.

The problems and deficiencies of the prior art centralized controls are solved, according to the present invention, by the use of distributed processing units (DPUs) which in addition provide the following advantages: A first advantage can be seen in the modularity and configurability of distributed control. An elevator control based on DPUs is localizing the processing according to functions. This will produce a control in which the processing for a function is performed locally, in the respective portion of the control system. With commonly defined interfaces, different functions can be added simply by adding the necessary hardware and DPUs. This will make it easier to build up a system with the desired features without affecting other DPUs, thus the modularity and configurability. This also makes it easier to add more functions in the future on a given job with a minimum amount of engineering work. Another advantage can be seen in the simplification of the control structure as a result of distributed processing. The control system is devided into different modules, each performing a defined set of tasks. Thus, the development and maintenance of the control system is simplified due to its modular nature. By specifying pre-defined interfaces, each module can be developed independently and concurrently to reduce the overall system development time. This reduces time to market, development costs and simplifies software maintenance. It has also been proved, that the system according to the invention exhibits an improved overall reliability and safety because there is no single point of failure and degraded operation modes are possible.

The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in the light of the accompanying drawings in which:

Fig. 1: is a schematic representation of a conventional elevator group, using an industrial computer for performing centralized control on three elevators.

Fig. 2: is a schematic representation of an elevator system utilizing a neural network based distributed control according to the present invention

Fig. 3: is a representation of the neural network structure used to implement the distributed control according to the invention

In the Fig. 1, the elevators of an elevator group are designated by A, B and C, wherein a car 2 is guided in an elevator shaft 1 for each elevator and is driven in a known manner by a hoist motor 3 by way of a hoisting cable 4 to serve sixteen floors E1 to E16. Each drive 3 is controlled by a drive control whereby the target value generation, the regulating functions and the start-stop initiation are all realized by means of an industrial computer 5. Measuring and adjusting elements 6 are connected to the industrial computer 5 by a first interface IF1 and an elevator bus 7. Each car includes a load measuring device 8 to determine when passengers enter and leave the elevator car, a call indicating device 9 signalling the respective operational state Z of the car, a stop indicator 10 and a car operating panel 11. The devices 8, 9, 10 and 11 are connected through a car bus 12 with the computer 5. Car calls are recorded in the elevator cars A, B and C by suitable push button arrays incorporated in the car-operating panel 11. They are then serialized and transmitted by way of the car bus 12 and the interface CIF to the industrial computer 5 along with any other car-related information.

Provided on the floors E1 to E16 are call registering devices 8 in the form of suitable push-buttons 13 such as an "up" hall call push button 14 located at the lowest floor E1, a "down" hall call push button 15 located at the highest floor E16 and "up" and "down" hall call push buttons 16 located at each of the intermediate floors E2 to E15. Like the car calls, the hall calls are serialized and transmitted by way of the floor bus 17 and the input interface ICF to the industrial computer 5, where they are allocated for service to the individual cars 2 in the sense of a demanded function profile by the use of a special hall call allocation algorithm.

Fig. 2 shows the elevator control system based on distributed control concepts. It uses Neuron Chip based local operating networks (Lonworks) by Echelon Corporation which is a new technology promissing better opportunities for creating lower cost distributed control systems with unique means of implementing distributed control algorithms. The underlying pricipal of the technology involves creation of a system with Distributed Processing Units (DPU`s). These DPU`s possess intelligence to sense and control local devices and send updates to other DPU`s in the system. All distributed processing units DPU operate automatically, independently and autonomously under management of software stored in each of them. They are simply connected to each other via one or more available communications media 18 thereby sharing a common, message-based communication protocoll. This makes it possible to confine the wiring to local levels and serially transmit device status to different points within the system. Thus, greatly reducing the overall wiring efforts. Each DPU of such a system has intelligence, not only to transmit messages between different points within the system, but also for performing control algorithms. By properly distributing control functions to different DPU`s, the necessity of having a centralized processor can be eliminated.

This is illustrated in the diagram of Fig. 2. Here the control system is made up of several intelligent DPU`s which are connected to each other by a communications medium 18. The number of DPU`s varies depending on the requirements of the control system, which need not be arranged on the number of elevators and floors, but on the required processing capacity. However, the functions performed by any given DPU does not change. Located on three floors E1, E2, E3 there are floor processing units FPU in the corridor fixture boxes 20 of each floor E1, E2, E3 and in the fire control center 21. Located in the elevator

cars 2 there are car processing units CPU for door operations, position indicator, landing system and car call features. There are further group processing units GPU and signalling processing units SPU located at the machine room 22. The floor processing units FPU and the car processing units CPU perform functions associated with its sensor devices and its actuator devices and perform the necessary control functions. In addition to this, they broadcast the latest states of the critical devices to inform other DPU`s in the system. The information thus received by other DPU`s along with their local device states is used in making control decisions that it is responsible for. The group processing units GPU include mainly hall call assignment functions, whereas the signalling processing units SPU relate to transmission functions for interprocess communication. Thus, a completely modular system can be created with distributed control functions.
An example of how a typical elevator operation is carried out by such a system is described with reference to Fig. 2. If a corridor call button 25 at 3rd floor is pressed by a passenger, the floor processing unit FPUa located in the corridor fixture box 20 at that floor recognizes it and latches it, if an elevator A,B,C is in service. This information is then transmitted to a first group processing unit GPUa in the machine room 22. Group processing unit GPUa is responsible for performing the evaluation calculation for determining hall call assignments to cars 2 and for performing group management of the cars 2 on the basis of the evaluation calculation result by controlling the drive unit 26 which in turn controls the movement of the elevators A,B,C. Once the information regarding the demand at 3rd floor is received, the group processing unit GPUa initiates commands to move the assigned elevator, which in this case shall be elevator A, towards the 3rd floor. As the elevator A moves through the building, the car processing unit CPUc which monitors the landing system, updates other distributed processing units DPU`s as the elevator A passes the floors E1.... Upon receiving this updates, the floor processing unit on the third floor FPUa changes the position indicator 27 to the appropriate floor position and direction. At the same time, the first group processing unit GPUa also receives the landing system update from the car processing unit CPUc and based on this information, it decides whether to continue the travel or to stop at the next floor. If the next floor is the target floor, the second group processing unit GPUb changes the commands to the drive unit 26 so as to stop at that floor. Once the elevator has began its slowdown, the second group processing unit GPUb broadcasts this information over the network. When the floor processing unit on the third floor FPUa receives this information, it cancels the corridor call being answered and at the same time turns on the hall lantern 28 for it. When the elevator A reaches exact level position, the group processing unit GPUb gets an update from the landing system car processing unit CPUc whereby the drive unit 26 is commanded to stop the elevator there and the second group processing unit GPUb is informing the door processing units CPUa and CPUb that the elevator has been stopped at the target floor. At this time CPUa and CPUb which are responsible for controlling door operation, command the doors to open and then to close after a pre-defined time. With all this, the demand at the 3rd floor is completed. The described typical elevator operation involves the exchange of data between the various distributed processing units DPUs. To this end signaling processing units SPUa, SPUb,... are provided for causing the group processing units GPUa and GPUb to communicate with each other through a first data field 29 and causing the car processing units CPUa, CPUb,... to communicate with each other through a second data field 30. As illustrated in the above example, a completely modular system can be created without a need for a central processing unit as designated with 5 in Fig. 1. By distributing the processing responsibilities of the system, tasks become much simpler and the load balance may be averaged. This simplicity is directly reflected in the system development cycle, and the ease of maintenance. For load averaging a distributed processing unit which has a heavy load may be temporarily exempt from process execution in practice. If even one of the
group processing units GPUa, GPUb, ... is operational group control can be performed, thereby assuring reliability in this respect. Therefore, high reliability and high system efficiency will be achieved through cooperative distributed control implemented by the individual distributed processing units DPU.

Fig. 3 illustrates the neural network structure used to implement the distributed control for elevator dispatching and back-up architecture. A multi car dispatching model was selected by applying neuron MC 143150 chip for the low cost and performance. The car to be allocated to a hall call is selected on the basis of the results obtained using the neural net corresponding to the neurons of the humain brain. The neural net includes an input layer, an output layer and an intermediate layer provided between the input and output layers. In the intermediate layer weighting factors are applied in combining signals from the nodes of the input layer and in distributing signals to the output nodes. The weighting factors are variable and are appropriately changed and corrected through learning so as to achieve a more adequate car allocation. Different sets of learning factors may be applied at different times or under different detected conditions of passenger loading. The learning (correction of the network) may be performed using the back propagation method. The back propagation is a method of correcting the weighting factors using errors between the output data of the network and desired output data created from surveyed data or control objective values.

Each main node contains its own Estimated Time of Arrival-software to perform token ring algorithm for the car to car communication and the back-up architecture as designed. Both guarantee the reliability for the bank service.
In this dispatching model the nodes A0,B0,C0,D0,... are the main nodes (MC143150) for all bank cars, nodes A1,A2,A3,... are the auxiliary nodes (MC143120) for each car, and the nodes Aa,Ba,Ca,Da,... are the backup nodes (MC143150) for the main nodes of all cars A,B,C,D.
Each main node contains its own ETA-calculation software to perform Token Ring algorithm for the car to car communication to guarantee the reliability for bank service rather than just have one node calculate ETA. Neuron Network Management also assures the concurrancy of the signal transmission among the auxiliary nodes A1,A2,A3,... to the main nodes A0,B0,C0,... The 3150 chip provides 64 KB for user program and goes through network common port 34 to communicate with other nodes.

For the critical nodes like main nodes A0,B0,C0,... additional backup nodes Aa,Ba,Ca,... can be used as shown. Each node pair 35 consists of a main node and a backup node. It begins for incoming data and also follows for outgoing data by a multiplexer 36. In the backup node side the consistency check software constantly sends out signals to check the network common port 34 and the application I/O port 37 of the main node. If an error is found, a signal is sent out to select the backup node Aa,Ba,Ca,... from the node pair 35 for the data communication. When the system is installed, all the nodes have their own identifications, even the backup nodes Aa,Ba,Ca,... . All the related nodes are able to look for backup nodes when a common error occurred.

The present invention is not limited to the particular embodiment described above. Various changes and modifications may be made without departing from the spirit and scope of the invention.

REFERENZLISTE

1)	elevators; elevator group	A,B,C
2)	elevator shaft	1
3)	car	2
4)	drive	3
5)	hoist cable	4
6)	16 floors	E1....E16
7)	industrial-computer	5
8)	measuring - and setting members	6
9)	1. interface	IF1
10)	elevator bus	7
11)	load measuring equipment	8
12)	operating state	Z
13)	operating state signalling equipment	9
14)	stop indicator	1o
15)	car operating panel	11
16)	car bus	12
17)	interface	CIF
18)	pushbuttons	13

19)	up hall call pushbutton	14
20)	down hall call pushbutton	15
21)	up and down hall call pushbuttons	16
22)	floor bus	17
23)	distributed processing units	DPU
24)	communication media	18
25)	floor processing units	FPU
26)	corridor fixture box	20
27)	fire control center	21
28)	car processing units	CPU
29)	group processing units	GPU
30)	signalling processing units	SPU
31)	machine room	22
32)	sensor device	23
33)	actuator device	24
34)	corridor call button (at 3rd floor)	25
35)	floor processing unit: floor 3	FPUa
36)	floor processing unit: floor 2	FPUb

37)	floor processing unit: floor 1	FPUc
38)	fire control processing unit	FPUd
39)	first group processing unit	GPUa
40)	second group processing unit	GPUb
41)	drive unit	26
42)	front door car processing unit	CPUa
43)	rear door car processing unit	CPUb
44)	landing system car processing unit	CPUc
45)	position indication car processing unit	CPUd
46)	car call feature car processing unit	CPUe
47)	position indicator	27
48)	third group processing unit	GPUd
49)	hall lantern	28
50)	first data field	29
51)	second data field	30
52)	main nodes	A0,B0,C0...
53)	auxiliary nodes	A1,A2,A3...
54)	back-up nodes	Aa,Ba,Ca...

Claims

1. An intelligent distributed control for elevators comprising a plurality of elevators arranged in conventional manner for servicing a plurality of floors of a building, including
a group controller, with hall call registering devices disposed at each of the floors to originate hall calls for up and down service at each of said floors, for exchanging signals with each of said elevators and for controlling the operation of said elevators in response to said hall calls and in response to signals received from said elevators, further including for each of said elevators a car, a car drive for providing and arresting the motion of said car, and a car controller for providing signals indicative of conditions of said car, for controlling said car motion, means to cause said car to move in a selected up or down direction and to stop in response to said signals indicative of conditions of said car and to signals received from said group controller
whereby
said group controller comprises a signal processor responsive to said signals indicative of conditions of each of said cars for providing for each car, upon generation of a hall call an evaluation calculation and an optimum elevator car is selected on the basis of an evaluation calculation result and dispatched to answer said hall call,
characterized by
    - the control comprising distributed processing units (DPU) and being preferably structured as a neural network, with input, intermediate and output layers, whereby the nodes of the neural network are implemented by the distributed processing units (DPU).
    - floor processing units (FPUa,FPUb,...) arranged on the floors (E1,E2,...) for controlling the corridor fixture box (20) of each floor and autonomously inputting/outputting information associated with

said floor,

- car processing units (CPUa,CPUb,...) arranged in each car (2) of the elevators (A,B,...) for controlling each car (2) and autonomously inputting/outputting information associated with that car (2),
- group processing units (GPUa,GPUb,...) arranged in the machine room (22) for performing the evaluation calculation for determining hall call assignments to cars (2) and for performing group management of the cars (2) on the basis of an evaluation calculation result; and
- one or more signalling processing units (SPUa,SPUb,...) provided for causing said group processing units (GPUa,GPUb,...) and said floor processing units (FPUa,FPUb,...) to communicate with each other.

2. The intelligent distributed control according to claim 1, characterized thereby, that in each car (2) there are provided a first door processing unit (CPUa) for front door operation, a second door processing unit (CPUb) for rear door operation, a landing system processing unit (CPUc) for the landing system, a position processing unit (CPUd) for position indication and a car call processing unit (CPUe) for car call features.

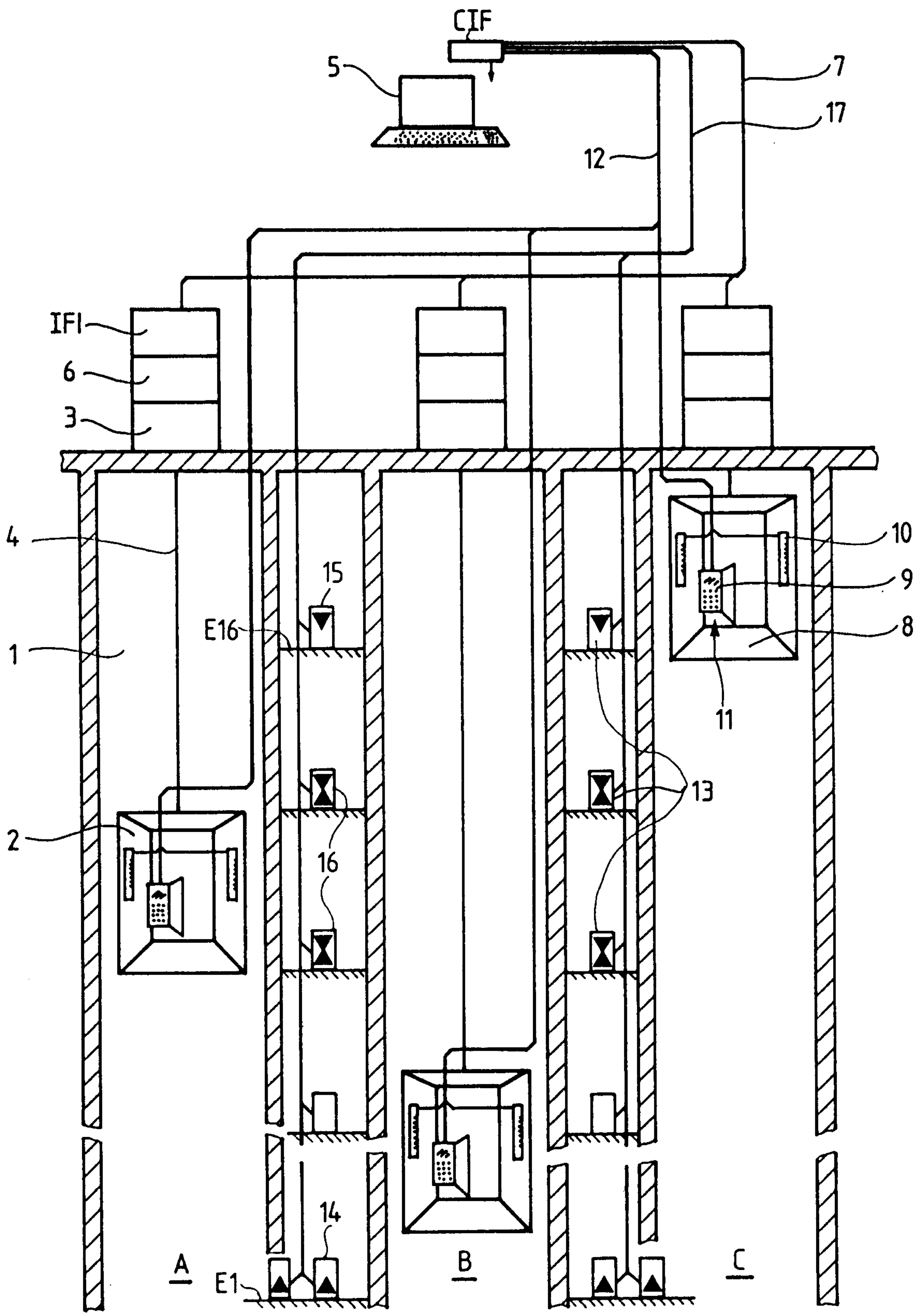
3. The intelligent distributed control according to claim 1, characterized thereby, that the device status is transmitted serially to the various distributed processing units (DPU) within the system.

4. The intelligent distributed control according to claim 1, characterized thereby, that said intermediate layer is containing first weighting factors between the individual nodes of said input layer and the individual nodes of said intermediate layer and second weighting factors between the individual nodes of said intermediate layer and the individual nodes of said ouput layer.

5. The intelligent distributed control according to claim 1, characterized thereby, that the neural network contains main nodes (A0,B0,C0...), and auxiliary nodes (A1,A2,A3...), whereby each main node (A0,B0,C0...) is connected in parallel with a back-up node (Aa,Ba,Ca...).

6. The intelligent distributed control according to claim 1, characterized thereby, that each main node (A0,B0,C0...) contains its own ETA-software to perform token-ring algorithm for car to car communication.

Fig. 1



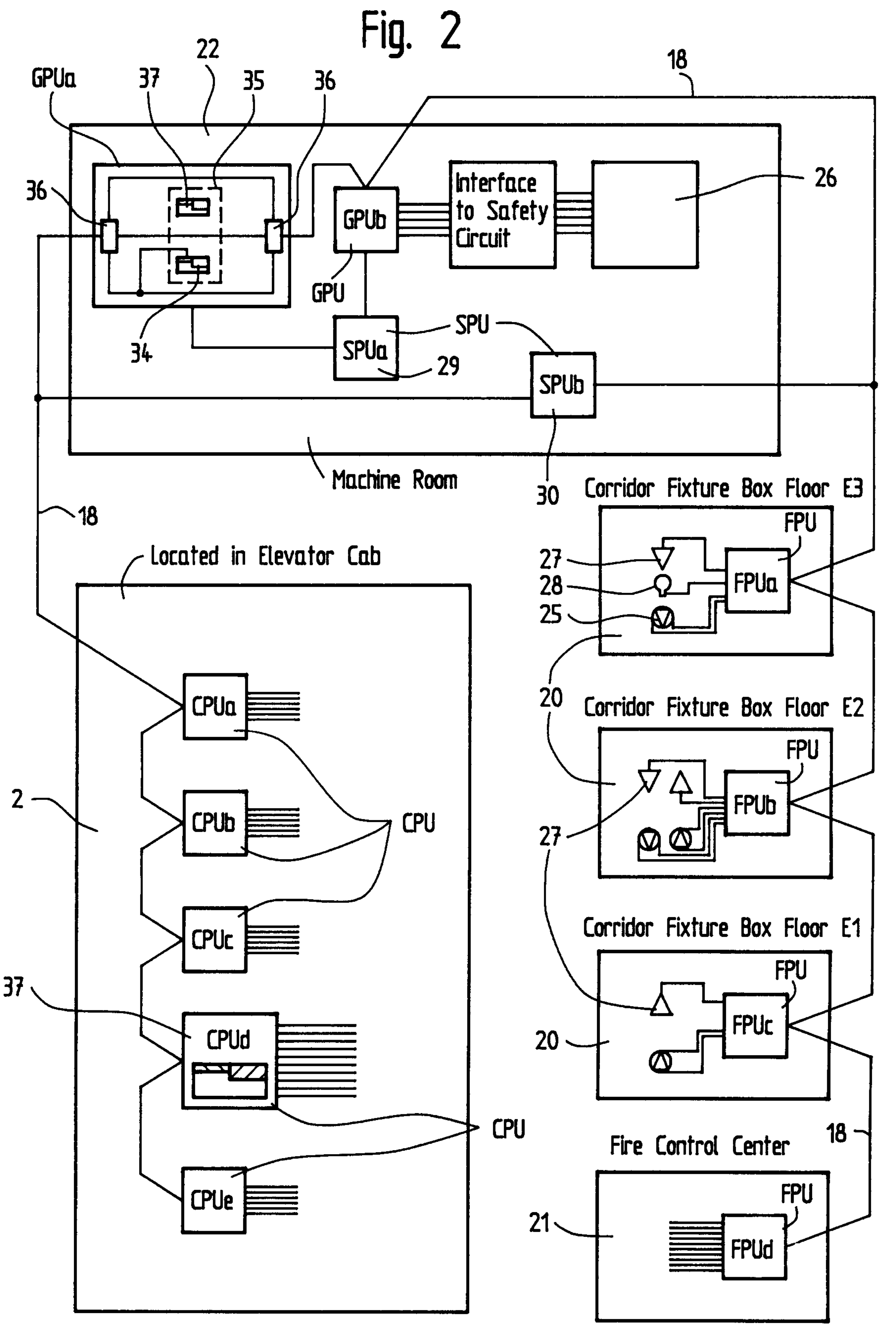


Fig. 2
22
GPUa
37
35
36
18
36
Interface to Safety Circuit
GPUb
26
GPU
SPU
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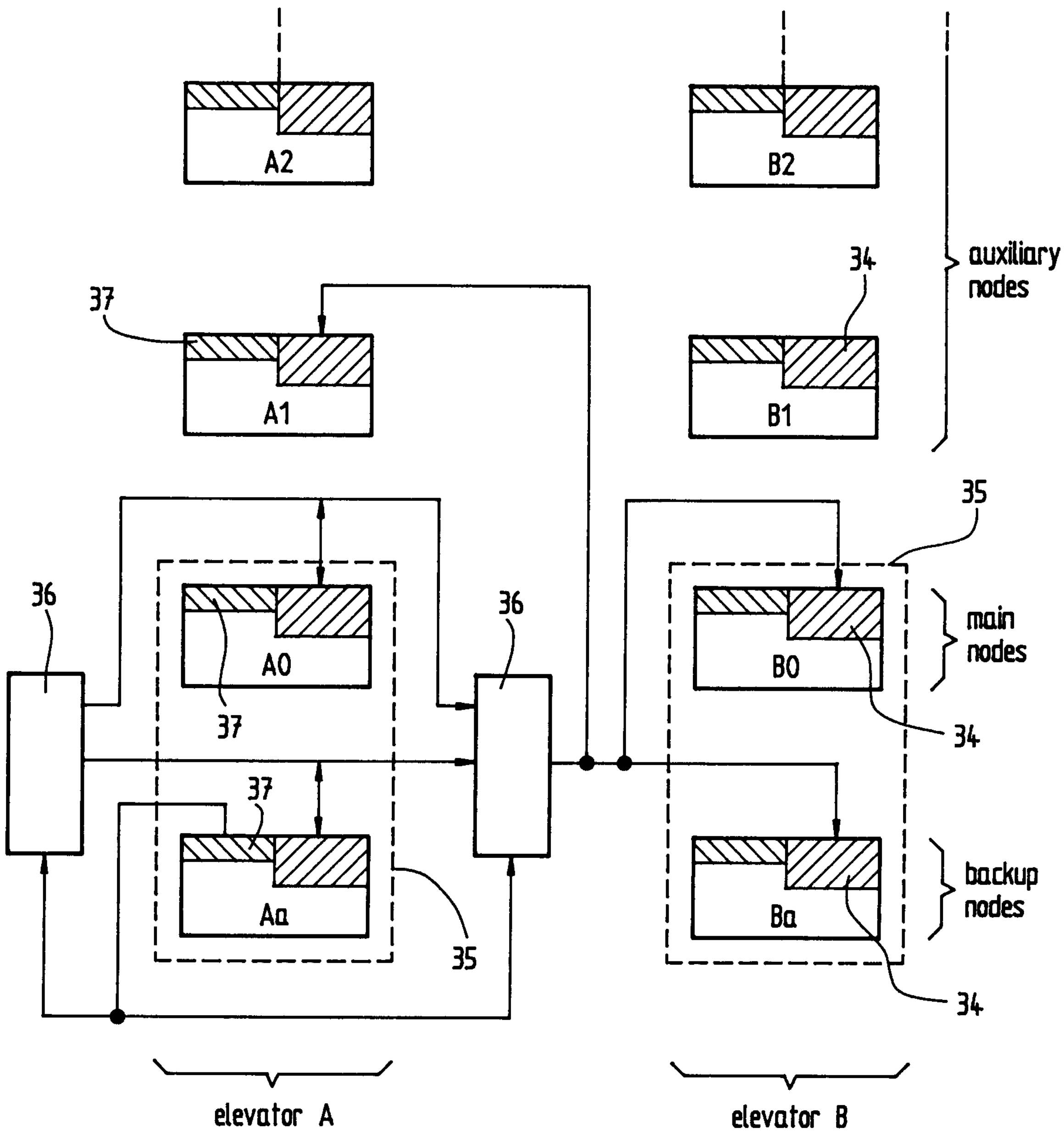
SPUa
29
SPUb
Machine Room
30
Corridor Fixture Box Floor E3
18
FPU
Located in Elevator Cab
27
28
FPUa
25
CPUa
20
Corridor Fixture Box Floor E2
FPU
2
CPUb
CPU
FPUb
27
CPUc
Corridor Fixture Box Floor E1
37
FPU
CPUd
FPUc
20
CPU
18
Fire Control Center
CPUe
FPU
21
FPUd

Fig. 3


A2
B2
34
auxiliary nodes
37
A1
B1
35
36
36
A0
B0
main nodes
37
34
37
backup nodes
Aa
Ba
35
34
elevator A
elevator B

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EUROPEAN SEARCH REPORT

Application Number
EP 94 12 0379

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US-A-5 012 899 (IWATA) * column 3, line 24 - column 4, line 25 * * figure 1 * ---	1-3	B66B1/18
A	GB-A-2 246 214 (MITSUBISHI D.K.K.) * abstract * * figure 3 * ---	1,4,5	
A	PATENT ABSTRACTS OF JAPAN vol. 18, no. 2 (M-1536) 6 January 1994 & JP-A-52 046 633 (FUJITEC CO LTD) 24 September 1993 * abstract * ---	1,4,5	
A	US-A-4 350 226 (SHEETY ET AL.) * column 3, line 43 - line 58 * * figure 1 * ---	1,3	
A	US-A-4 766 978 (BLAIN ET AL.) * column 3, line 68 - column 4, line 17 * * column 6, line 33 - line 45 * * column 8, line 34 - line 60 * -----	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B66B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 February 1995	Salvador, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document