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(54) Computer-aided fault diagnostic device for a complex technical system

(57) A computer-aided fault diagnostic device is suitable, in particular, for a motor vehicle and contains a diagnostic sequence preparation stage in which a knowledge base with a structure model, a function model and a fault model is stored, and also contains a diagnostic execution stage.

A fault diagnostic device is proposed in which the basic structure of the fault model is produced automatically by the diagnostic sequence preparation stage from the structure model and the function model, in that for each knowledge base module of a subsystem precisely one fault model root object is derived and for each function area one fault object is derived, the fault object of a hierarchically subordinate function area being hierarchically subordinate to the fault object of the hierarchically superordinate function area, and for each sub-function area which is formed by opening interfaces of a function area from a hierarchically superordinate function area or sub-function area in accordance with a precedence list, a fault object is derived which is hierarchically subordinate to the fault object of the associated, hierarchically superordinate function area or sub-function area.

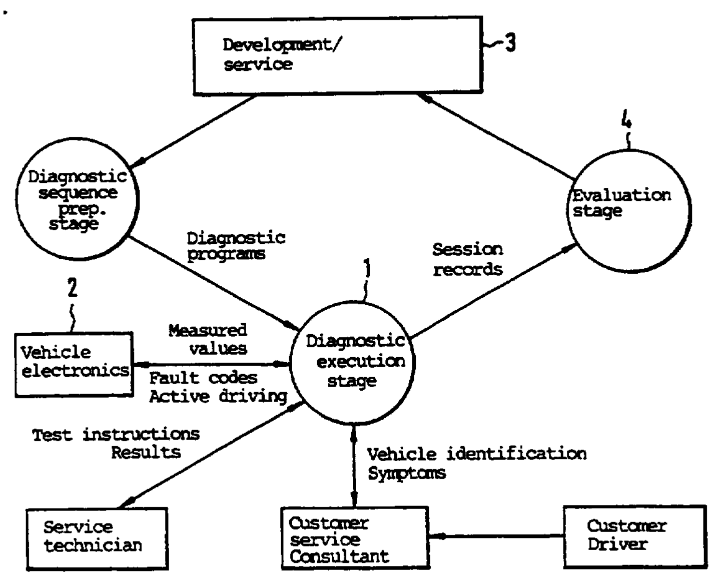


FIG. 1

GB 2 303 231 A

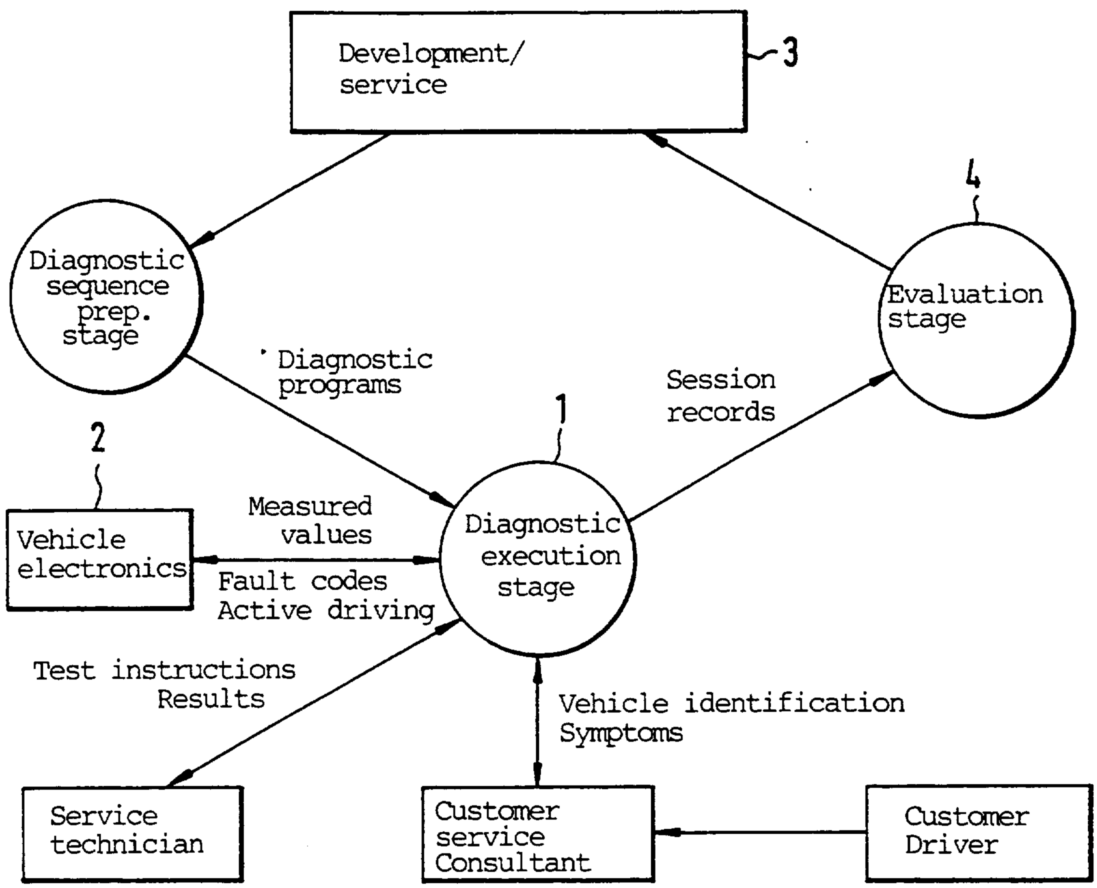

Development/ service
3
Diagnostic sequence prep. stage
4
Evaluation stage
Diagnostic programs
Session records
1
2
Vehicle electronics
Measured values
Fault codes
Active driving
Diagnostic execution stage
Test instructions
Results
Vehicle identification
Symptoms
Service technician
Customer service Consultant
Customer Driver

FIG. 1

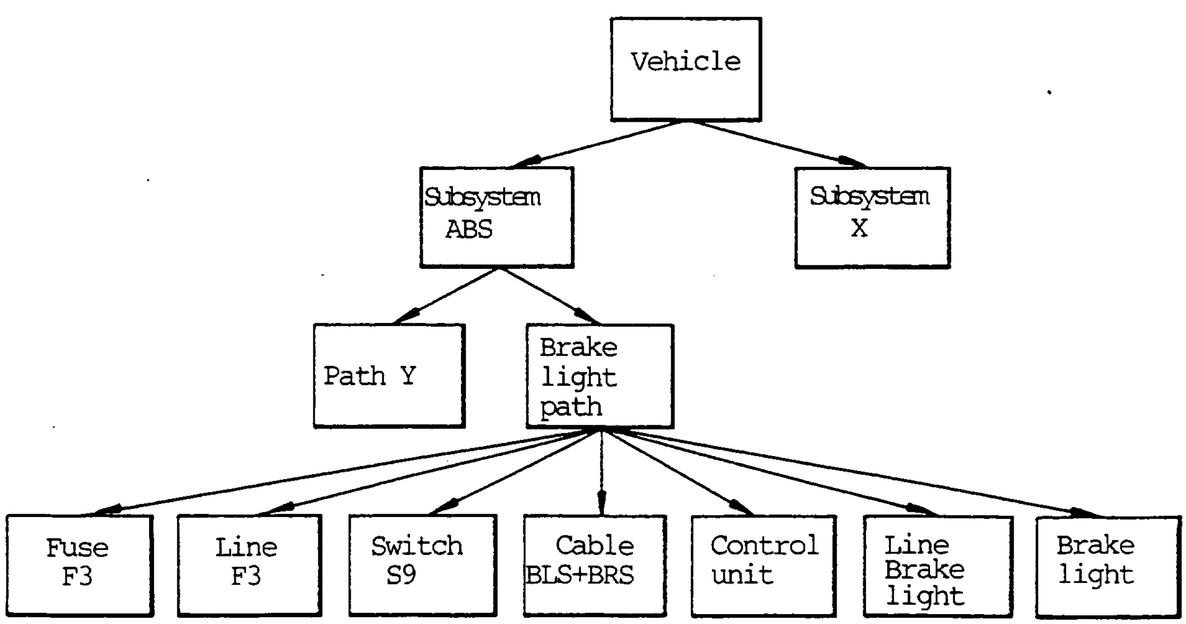

Vehicle
Subsystem ABS
Subsystem X
Path Y
Brake light path
Fuse F3
Line F3
Switch S9
Cable BLS+BRS
Control unit
Line Brake light
Brake light

FIG. 2

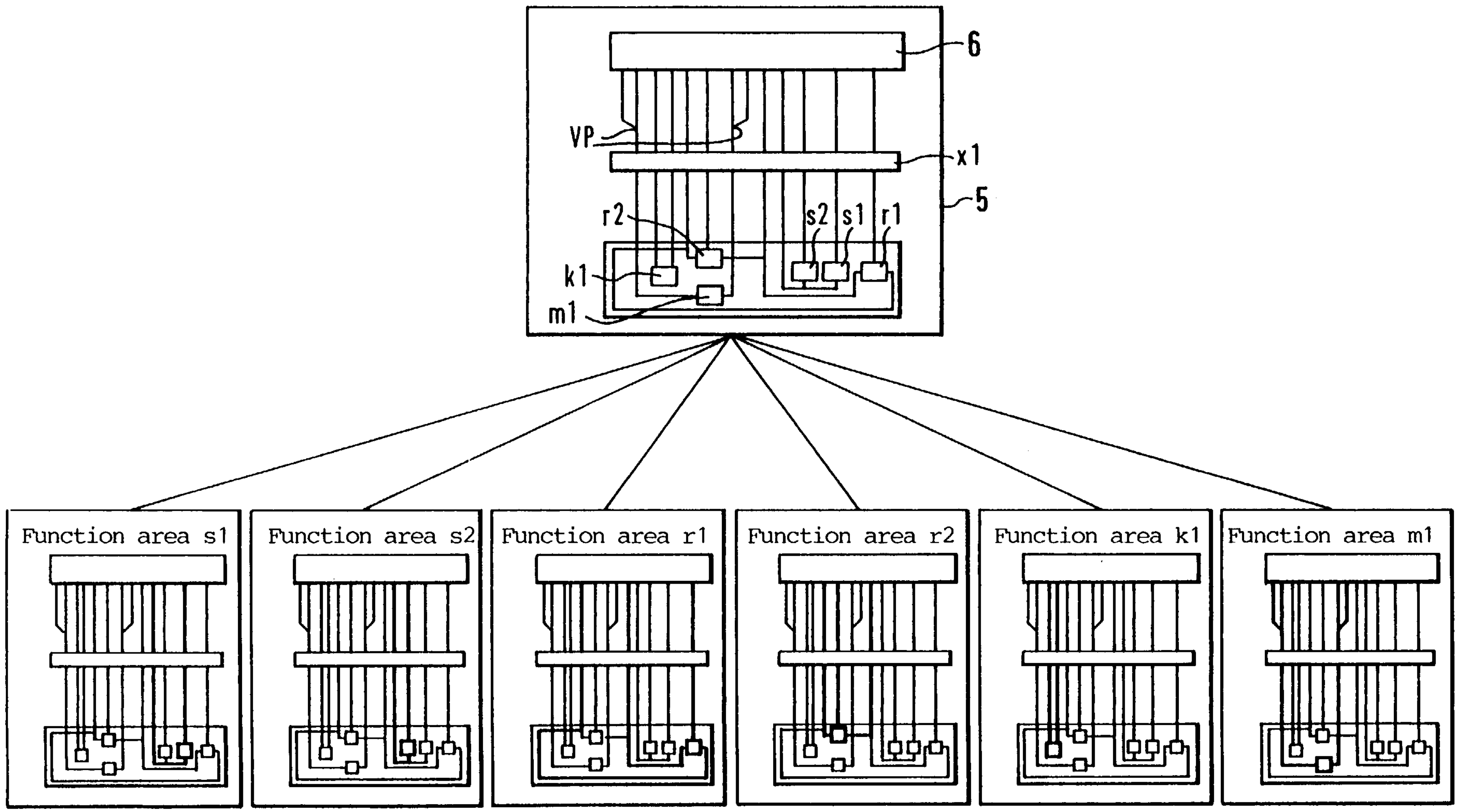

6
VP
x1
5
r2
s2
s1
r1
k1
m1
Function area s1
Function area s2
Function area r1
Function area r2
Function area k1
Function area m1

FIG. 3

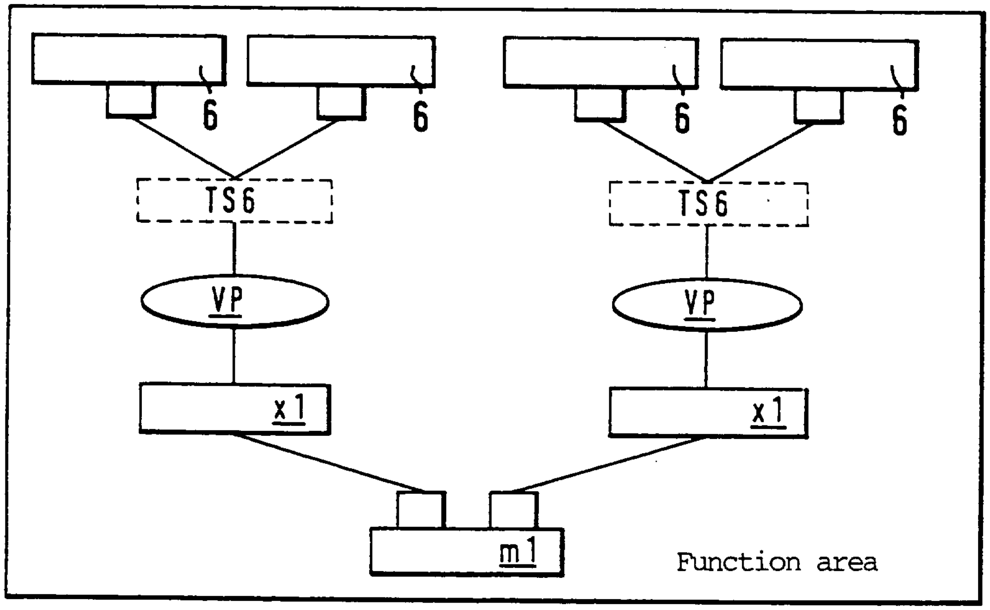

6
6
6
6
TS6
TS6
VP
VP
x1
x1
m1
Function area

FIG. 4

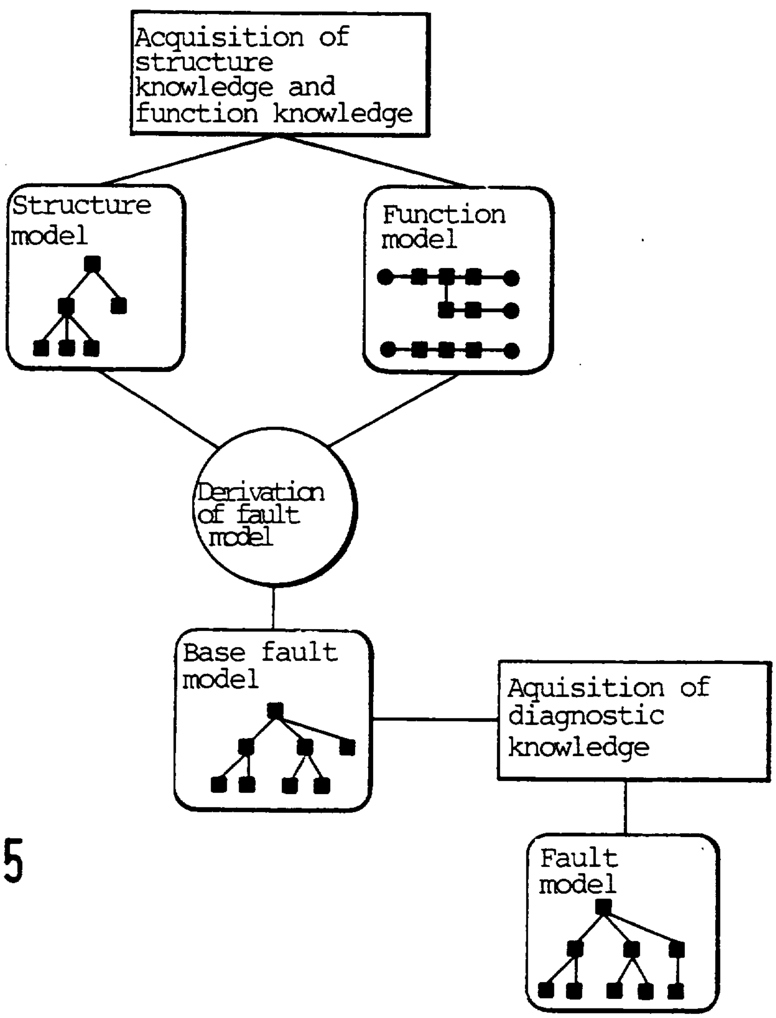
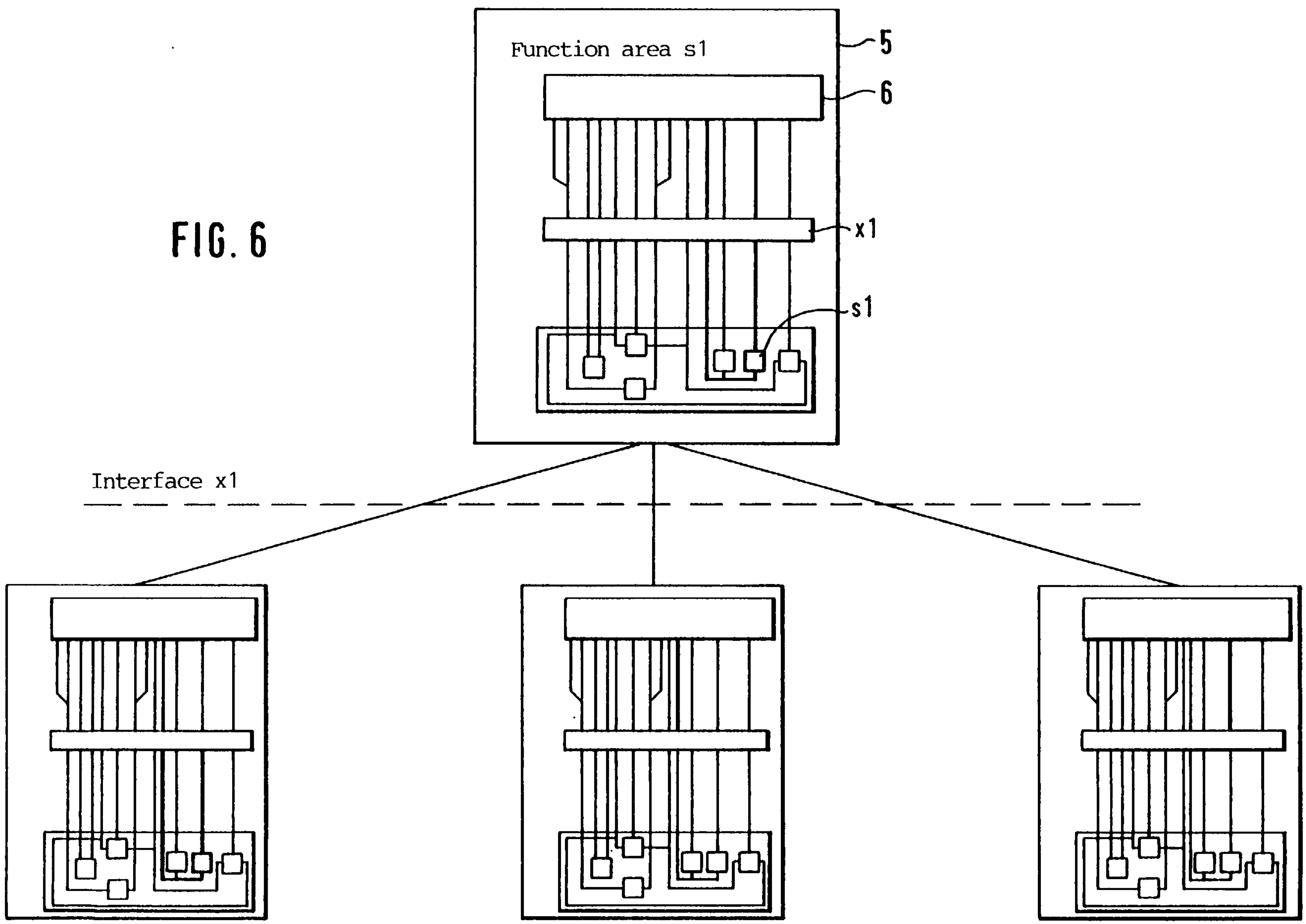

Acquisition of structure knowledge and function knowledge
Structure model
Function model
Derivation of fault model
Base fault model
Aquisition of diagnostic knowledge
Fault model

FIG. 5

FIG. 6



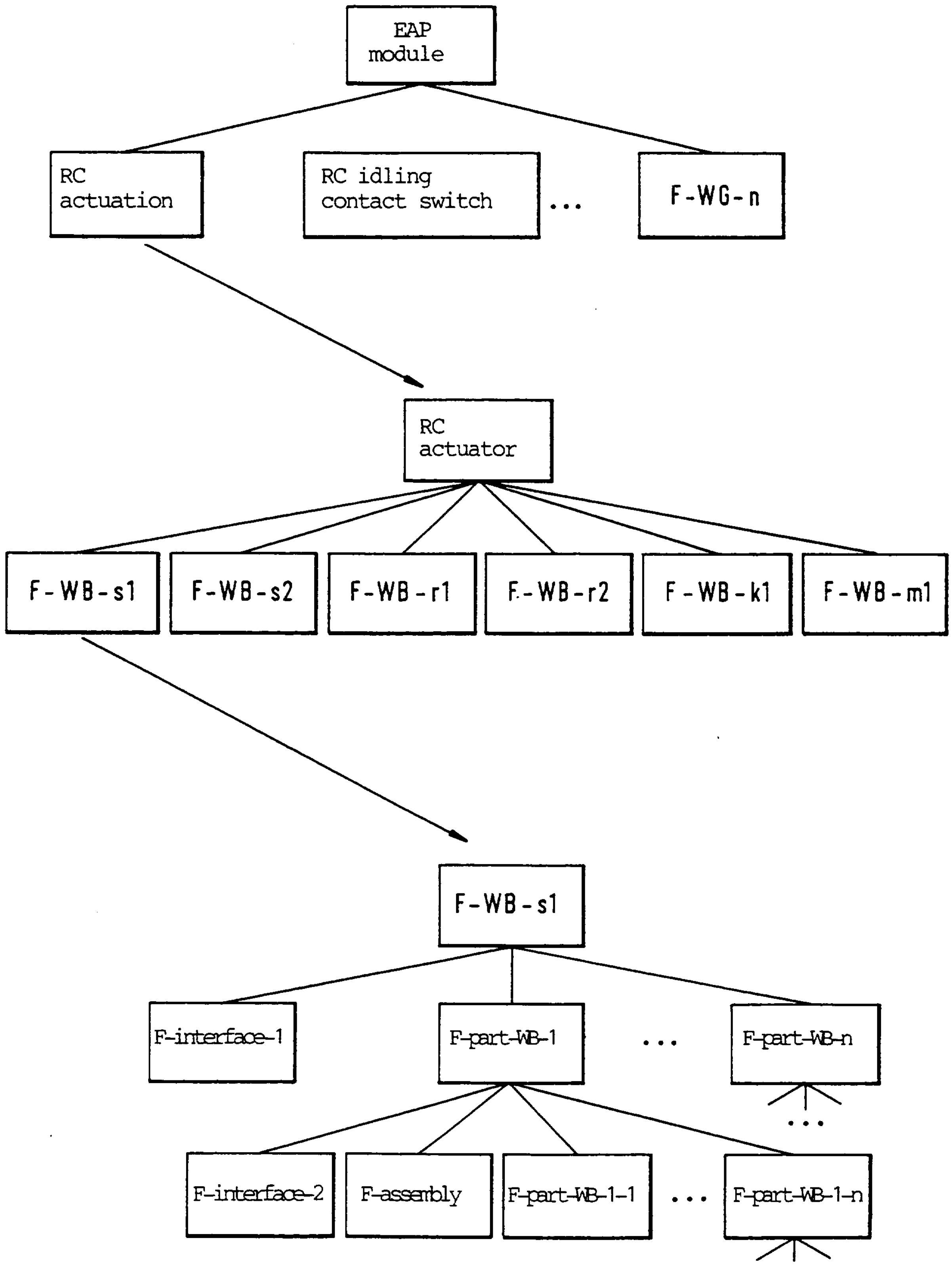

EAP module
RC actuation
RC idling contact switch
...
F-WG-n
RC actuator
F-WB-s1
F-WB-s2
F-WB-r1
F-WB-r2
F-WB-k1
F-WB-m1
F-WB-s1
F-interface-1
F-part-WB-1
...
F-part-WB-n
...
F-interface-2
F-assembly
F-part-WB-1-1
...
F-part-WB-1-n
...

FIG. 7

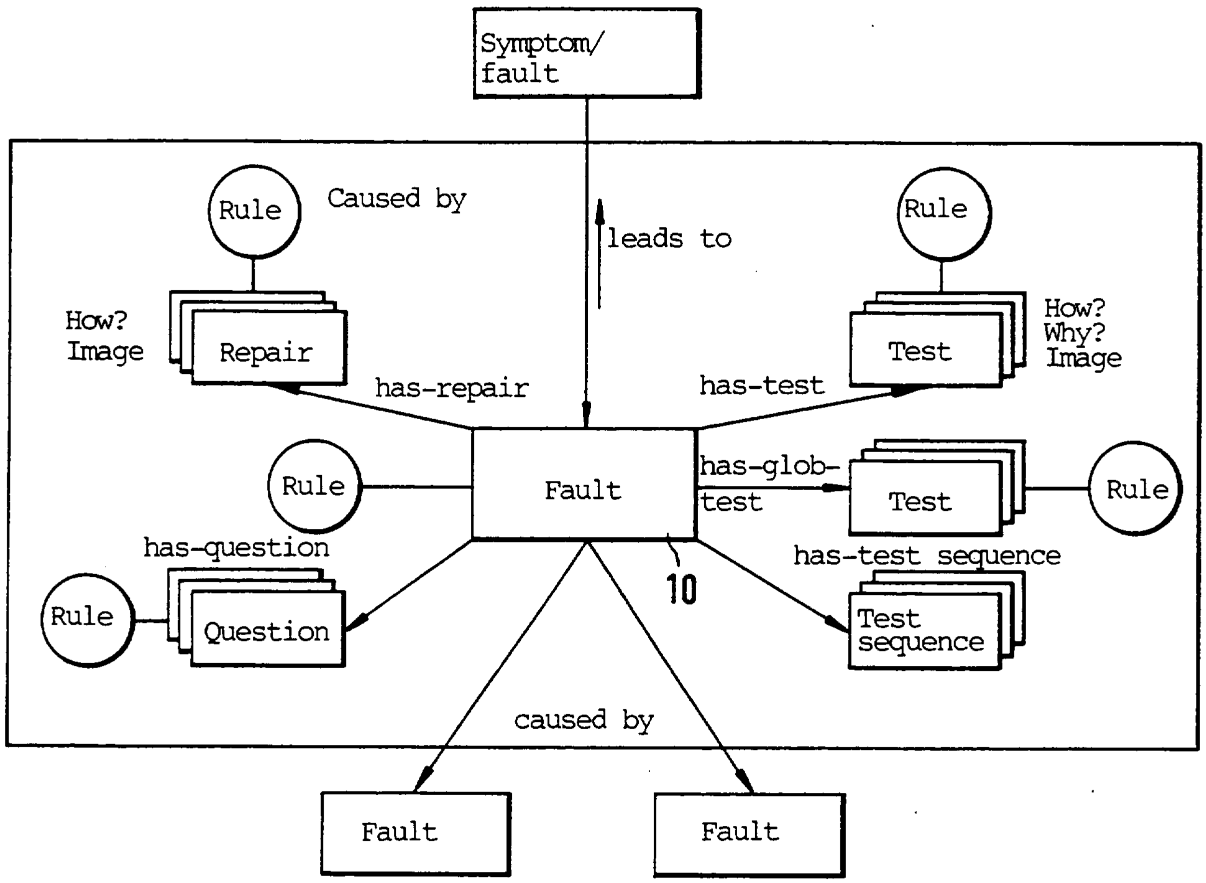

Symptom/
fault
Rule
Caused by
leads to
Rule
How?
Image
Repair
has-repair
has-test
Test
How?
Why?
Image
Rule
Fault
has-glob-
test
Test
Rule
has-question
has-test sequence
10
Rule
Question
Test
sequence
caused by
Fault
Fault

FIG. 8

Computer-aided fault diagnostic device for a complex technical system

The invention relates to a computer-aided fault diagnostic device for a technical system which is complex, i.e. made up in modular fashion of a plurality of subsystems, and has a plurality of functions to be diagnosed, the technical system which is to be diagnosed to be, particularly but not exclusively, a motor vehicle.

The patent document US 5,099,436 describes a computer-aided fault diagnostic device for a complex technical system in which data which are detected while the system is operating are compared with an event-based representation of the system which contains a plurality of predefined events. In addition, a symptom-failure model and a fault model are provided in the said publication. These models are used to produce an ambiguity group with an order of precedence which serves in turn as a basis for a structure model analysis in which the system starts at the greatest probability of a fault in the ambiguity group.

Basic structural features of a computer-aided fault diagnostic device for a motor vehicle are described in the publications N. Waleschkowski, M. Schahn, W. Henrich, T. Forchert, K. Müller and J. Steinhart, "Ein wissensbasiertes Fahrzeug-Diagnosesystem für den Einsatz in der Kfz-Werkstatt" Grundlagen und Anwendungen der künstlichen Intelligenz [A knowledge-based vehicle diagnostic system for use in a motor vehicle workshop, Basic Principles and Applications of Artificial Intelligence], Springer-Verlag, 1993, page 277 and N. Waleschkowski, N. Schahn and T. Forchert, "Wissensmodellierung und Wissenserwerb am Beispiel der Fahrzeugdiagnose" [Modelling and acquiring knowledge with reference to the example of vehicle diagnostics], in the periodical "Künstliche Intelligenz" [Artificial Intelligence] KI 1/95, page 55. The contents of these two publications form the basis of the subject-matter of the present invention and are included herein by reference so that reference can be made to these publications with regard to the detailed description of components which are covered in detail therein. A fault diagnostic device as disclosed in the said publications contains a diagnostic sequence preparation stage with a knowledge base which can be conceived as a multidimensional structure, in which case, depending on the way in which the knowledge base is viewed, the structure model which represents the hierarchical structure of the technical system composed of the individual subsystems, the function model which represents the functional relationships between the individual subsystems or the fault model appears, which fault model represents the relationships between fault causes and their effects as well as suitable test sequences and repairs and thus determines the diagnostic sequence. Conventionally, a fault model is produced manually, which constitutes a large work expenditure and in particular also requires difficult design decisions which can often be made differently by different development personnel, which leads to fault models whose structure is influenced to a comparatively high degree by subjective factors. This in turn disadvantageously influences the desired well-defined nature and lack of ambiguity of the resulting diagnostic sequence.

The technical problem on which the invention is based is to provide a computer-aided fault diagnostic device of the type mentioned at the beginning which is capable of carrying out fault diagnostics automatically and reliably on a given technical system with diagnostic sequences which are as well-structured and uniform as possible, and which requires a comparatively small amount of work for the diagnostic sequence preparation prior to executing fault diagnosis.

According to the present invention there is provided a computer-aided fault diagnostic device for a complex technical system having a plurality of functions to be diagnosed, having

- a diagnostic sequence preparation stage in which a knowledge base is stored which contains a structure model relating to the hierarchical structure of the technical system composed of individual subsystems, a function model relating to the functional relationships between the individual subsystems and a fault model which determines the diagnostic sequence is automatically produced from the structure model and the function model and represents the relationships between fault causes and their effects as well as suitable test sequences and repairs, and

- a diagnostic execution stage for the interactive execution of fault diagnostics using the diagnostic sequence program prepared by the diagnostic sequence preparation stage,

wherein

- the fault model is based on a base fault model which is produced automatically by the diagnostic sequence preparation stage from the structure model and the function model, and for each knowledge base module which is assigned to a respective subsystem it derives precisely one fault model root object, for each associated, hierarchically highest-ranking function area in the function model it derives a fault object which is hierarchically subordinate to the associated fault model root object, for each associated, hierarchically subordinate function area in the function model it derives a fault object which is hierarchically subordinate to the fault object of the hierarchically superordinate function area, and for each associated sub-function area which is formed by opening interfaces in accordance with a precedence list which is produced it derives a fault object which is hierarchically subordinate to the fault object of the hierarchically superordinate function area or sub-function area.

In this device, the diagnostic sequence preparation stage automatically generates a basic fault model from the structure model and the function model in the stated, specific manner. It becomes apparent that, by virtue of its relatively uniform and optimized structure, a basic fault model which is produced automatically in such a way leads to well-defined and reliable diagnostic sequences, only a comparatively small amount of work being required in addition for the production of fault models.

A development of the invention supplements the fault diagnostic device to form a closed diagnostic process circuit, in that an evaluation stage evaluates the session records of diagnostic sequences and extracts from them information which can be used to update the knowledge base which determines the diagnostic sequence and, for this purpose, can be transmitted to the diagnostic sequence preparation stage.

A fault diagnostic device wherein, in order to execute a knowledge-base-controlled diagnostic sequence during which initially a short test for interrogating the control units present and for reading out data which relate to diagnosis, in particular fault codes stored in fault memories, is executed, then a check list is produced, subsequently a diagnostic entry test for marking individual areas of a subsystem, given by the check list, as a potential cause of faults is executed and a detailed check list is produced as a function of the result of this test, according to which detailed check list the actual fault search procedure is executed with reference to respective test instructions and, when a fault is detected, a repair instruction is prepared and a subsequent verification test is optionally executed, is particularly suitable for fault diagnostics in motor vehicles.

A fault diagnostic device wherein, in the base fault model produced automatically by the diagnostic sequence preparation stage from the structure model and the function model, a respective fault object is assigned to the interfaces themselves, has further improved properties by virtue of the fact that fault objects are assigned to the interfaces themselves.

A preferred embodiment of the invention is illustrated in the drawings and described below. In the said drawings:

Fig. 1 shows a schematic block diagram of a computer-aided fault diagnostic device for a motor vehicle with associated communication paths,

Fig. 2 shows a schematic view of a portion of the primary description plane of a knowledge-base structure model stored in the diagnostic sequence preparation stage of Figure 1,

Fig. 3 shows a schematic block diagram of a function group, relating to an electronic accelerator pedal EAP actuator, of a knowledge-base function model which is stored in the diagnostic sequence preparation stage of Figure 1,

Fig. 4 shows a schematic view of one of the function areas of the function group of Figure 3,

Fig. 5 shows a flow chart relating to the production of a fault model stored in the diagnostic sequence preparation stage of Fig. 1,

Fig. 6 shows a block diagram of one of the function areas of Figure 3 in order to illustrate the significance of an interface,

Fig. 7 shows a schematic view of that part of the fault tree of the fault model which relates to the EAP actuator in Figure 3, and

Fig. 8 shows a schematic block diagram of the local environment of a fault object of the fault model.

As is clear from Figure 1, the computer-aided motor-vehicle fault diagnostic device which is described by way of example contains, as a core element, a diagnostic execution stage 1, which is typically installed in a diagnostic computer device of a workshop. A customer services consultant whom a customer or driver approaches because of a fault in his motor vehicle can communicate with the said diagnostic computer device in order to indicate the vehicle identification and fault symptoms which may be known. The diagnostic execution stage 1 is capable of automatically executing on the respective vehicle a diagnostic sequence such as is prescribed by an associated diagnostic program which is made available to the diagnostic execution stage 1 by a diagnostic sequence preparation stage 2, which is typically located in a development control centre of the manufacturer of the vehicle. Depending on the vehicle and the fault symptoms indicated, the diagnostic execution stage 1 then controls a suitable diagnostic sequence accompanied by interaction with the service technician involved, who, depending on the sequence strategy, can retain the procedure proposed by the system or deviate from it on the basis of his own experience. Such strategies as user-guided strategies, strategies controlled by the user or a case-based strategy are known per se and do not require any more detailed explanation here. In this way, the necessary test instructions and test results are exchanged between the diagnostic execution stage 1 and service technician. In addition, when localizing a fault, the service technician if appropriate intervenes in the vehicle system by disconnecting assemblies from one another at interfaces or connecting measurement sensor systems and executing a remedy measure, for example exchanging an assembly which has been detected as faulty. During the diagnosis, the diagnostic execution stage 1 communicates with the vehicle electronics in order to acquire measured values and environmental data, which then themselves control the diagnostic sequence in a way prescribed by the diagnostic program, i.e. so that the next diagnostic step is determined as a function of a measured value. Furthermore, the diagnostic execution stage 1 is capable of actively driving actuators in the vehicle and thus of placing the vehicle in a specific state. For executing the vehicle communication during the diagnosis, use is made of a software module in the form of a so-called vehicle manager, which determines the present configuration of the vehicle and performs variant handling, for example automatic selection of the communication protocol, of the various control-device variants which are present. Furthermore, the communication between the vehicle and diagnostic execution stage 1 includes the transmission of diagnosis-related data, in particular stored fault codes if appropriate.

In order to prepare the necessary diagnostic programs for the diagnostic execution stage 1, the diagnostic sequence preparation stage 2 contains a stored knowledge base which comprises knowledge base modules which are assigned to a respective subsystem of the complex, modular technical system, here specifically of the vehicle. In order to represent knowledge, use is made of a structure model which relates to the structure of the technical system and its subsystems, of a function model which relates to the method of operation of the subsystems, of a fault model in which the knowledge relating to the relationships between faults and symptoms and between faults and their causes is contained, as well as of a case base relating to information regarding situations and cases. The knowledge base can be conceived as a multidimensional structure from which the various aforesaid models result depending on the point of view, for example the structure model results from viewing the knowledge base by means of the "has part" relation, while the "caused by" relation permits the fault model to be viewed. In order to produce and update the respective structure model and function model, the necessary input information is fed into the diagnostic sequence preparation stage 2 via an input station 3 within a development environment or service environment, the said diagnostic sequence preparation stage 2 then automatically generating, as described in greater detail below, a base fault model from the structure model and the function model. By means of an evaluation stage 4, a continuous diagnostic process circuit is formed in which the evaluation stage 4 evaluates the diagnostic session records of the diagnostic execution stage 1 according to information which is of interest to the knowledge base in the diagnostic sequence preparation stage 2. This information is transmitted from the evaluation stage 4 to the input station 3 in order to be passed on to the diagnostic sequence preparation stage 2, which can subsequently update the knowledge base in accordance with the diagnostic results. The evaluation stage here may either be located in the respective workshop or else in a central development or service department of the vehicle manufacturer.

More precise details on the knowledge base which determines the diagnostic sequence are given below. The structure model describes the composition of the vehicle from the individual assemblies, a primary description plane comprising a structure tree such as is illustrated in a partial view in Figure 2 for an "anti-lock brake system" subsystem. The connection arrows here each represent the "has part" relation, i.e. a hierarchically subordinate component is part of the associated hierarchically superordinate component. On a secondary description plane, each unit of the structure model is assigned knowledge relating to possible faults, test methods and repairs.

The function model describes the interaction between the assemblies of the vehicle and between the individual subsystems. The description is made by modelling the functional relationships which exist between the individual assemblies of the structure model. The modelling in the function model takes place on a plurality of planes, which is clarified below in Figures 3 and 4 with reference to the example of an actuator 5 of an electronic accelerator pedal [abbreviated below as EAP] as a subsystem of the vehicle. Initially, a separate knowledge base module is defined for the respective subsystem, here the EAP actuator 5 represented at the top of Figure 3 as a block diagram. This subsystem is then broken down into individual function groups which generally contain the connections of an associated control unit to in each case one peripheral component, such as actuators, relays, switches or other control units. Subsequently, a function area is defined for each functional relationship contained in this function group. Thus, for example, a function group with a relay can be broken down into one function area for the control circuit and one for the working circuit. In the example of Figure 3, the EAP actuator 5 contains a control unit 6 which is connected via electrical lines to the function processing units, such as actuators, sensors, etc. Specifically, there are two potentiometers r1, r2, two switches s1, s2, one clutch k1 and one motor m1 here. The associated function group thus consists of six function areas which are assigned to these six components, the respective function transport paths, i.e. in this case the electrical connection lines, are highlighted in bold in the respectively associated block diagram of the lower part of Figure 3. In Figure 4, the logical structure of the function area for the actuator m1 is represented, the components with a continuous rectangular frame designating assembly aspects which are, if appropriate, provided with connection points which are symbolized by squares. The components which are outlined with an oval constitute function interface aspects, cf. the connection points VP in Fig. 3, while the components with a dashed outline represent interface aspects TS6. Here, interfaces are designated to be those points in the technical system at which diagnostic intervention is possible by interrupting the flow of the function. The interfaces provide the service personnel with particular test possibilities in order to identify faulty sub-function areas in the system by means of suitable measurements and to localize a fault by successively breaking down the system. Here, assemblies may also form interfaces, for example, disconnectable plug-in connector units. The connection lines in Fig. 4 represent the "has function" relation. As for the structure model, in addition to this primary description plane of the function model there is a secondary description plane which in turn contains knowledge relating to possible faults, test sequences, etc. for each component of the function model. Both the structure model and the function model are automatically derived from data relating to the composition of the vehicle, which data are stored in corresponding CAD/CAE systems and are fed to the diagnostic sequence preparation stage 2 via the input station 3.

A particular feature of the fault diagnostic device shown is that the diagnostic sequence preparation stage 2 automatically derives a base fault model, as is illustrated in the form of a flow chart in Figure 5, from the structure model and the function model. The derivation of the base fault model takes place in the following steps, starting from the structure model and function model which have been produced by means of the corresponding acquisition of structure knowledge and function knowledge. Initially, precedence lists for the interfaces in the function model are produced, so that the interfaces of each function area are arranged in an order of precedence. This order of precedence can be produced taking into account the outlay, for example with respect to accessibility or testing outlay, the usefulness of the fault localization, the probability of faults, i.e. the rate of occurrence of faults and the number of tests, i.e. the number of possible tests at an open interface. The subsequent production of the actual base fault model is illustrated in Figure 7 in turn in the case of the EAP actuator as representative of all the other subsystems of the motor vehicle.

Initially, precisely one root object in the fault model is derived for each knowledge base module in the function model, cf. EAP module in Figure 7, the identification data being transmitted from the knowledge base module in the function model to the root object in the fault model. Each function group of a subsystem is mapped onto a fault object in the fault model and made hierarchically subordinate to the root object. The connection lines in Figure 7 designate, from top to bottom, a "caused-by" relation or, in the opposite direction from bottom to top, a "leads-to" relation. In Figure 7, these are the fault objects for the actuator, idling contact switch etc. function groups. The fault objects for the function groups thus form the first plane in the fault tree. If a fault has already been assigned to the function group in the function model, this fault is inserted into the fault tree, whereas otherwise an empty fault object is automatically generated, the name of which fault object is derived from the name of the function group.

As the next step, each function area of a respective function group is mapped onto a corresponding fault object and made hierarchically subordinate to the fault object associated with this function group. This is illustrated in the central part of Figure 7 for the function group of the EAP actuator, whose six function areas are illustrated in Figure 3. If a fault has already been assigned to the respective function area in the function model, this fault is inserted into the fault tree. Otherwise, an empty fault object is automatically generated, its name being derived from the name of the function area.

In a subsequent step, the individual function areas are refined in that each possible fault in a function area is assigned faults in sub-function areas which arise from the function area as a result of the opening of an interface. The order in which the interfaces of the function area are opened is determined by the specification of their precedence in accordance with the precedence list produced at the beginning. If an interface is opened, then the function area generally breaks up into a plurality of sub-function areas. This is illustrated in Figure 6 by way of example for the function area s1 of one of the two switches of the EAP actuator 5 in accordance with Figure 3. The opening of the interface x1 there generates the three sub-function areas shown in the lower half of Figure 6. For each sub-function area, in each case a fault object is derived and made hierarchically subordinate to the fault object of the associated function area. Furthermore, those fault objects which are assigned to the interface itself are inserted next to the fault objects of the sub-function areas. The same procedure is adopted for the further sub-function areas until the respective sub-function area comprises only the smallest exchangeable or repairable unit whose assigned faults are then inserted next to the fault objects of the other sub-function areas of the same hierarchy. If a sub-function area comprises only a function interface object, i.e. an interface of a subsystem with another subsystem, this is inserted into the fault tree. This procedure of refining function areas is illustrated in the lower part of Figure 7 with reference to the function area s1 of one switch of the EAP actuator 5. If fault objects for paths, function areas, interfaces or components have already been given in the structure model and in the function model, these fault objects are inserted as additional fault causes under the respective associated faults in the fault tree. The faults already defined in the structure model and in the function model can also already have tests and repairs which are likewise transferred into the fault object in the fault tree. The second description plane, generated as a result of this, of a fault object 10, i.e. its local environment, is illustrated in Figure 8, which, with the labels provided, including the relations associated with the connection lines, is self-explanatory.

The automatic production of the base fault model by the diagnostic sequence preparation stage 2 is thus terminated. In order to complete the base fault model to form the definitive fault model, case knowledge, i.e. information regarding situations and cases, can be added in a diagnostic knowledge acquisition, as illustrated in Fig. 5. The described algorithm for the automatic derivation of fault models leads, with relatively little production outlay, to a reliable, uniform and well-structured fault model which forms a secure base for the execution of optimum diagnostic sequences by means of the diagnostic execution stage 1.

In order to further improve the derivation of fault models, generic [assembly] libraries may be provided in the diagnostic sequence preparation stage 2, in which libraries general knowledge relating to the individual system parts and their function components is stored. When new system components are present, the diagnostic sequence preparation stage 2 can use these generic libraries during the derivation of the fault model to execute a pattern comparison and as a result determine whether parts already contained in the knowledge base have the new system components, and if so which they are. These parts are then assigned fault objects which contain the already known knowledge relating to this, as a result of which the fault-model production is optimized and improved fault structures can be obtained.

A typical part of such a diagnostic sequence on the vehicle which can be executed by the fault diagnostic device in Fig. 1 is indicated below with reference to the example of a fictional fault in the form of a circuit interruption in the case of an arrangement of four solenoid valves in an electronic gearbox control of an automatic gearbox.

The diagnostic sequence starts with a rough vehicle identification, for example relating to design, engine number and gearbox number, etc, the inputting of customer complaints and a short test in which the control units in the vehicle are identified, in addition to an electronic gearbox control, for example, an anti-lock brake system control unit and an engine control unit, according to which the diagnostic execution stage 1 produces a corresponding check list. A service technician then activates the fault diagnosis with respect to the check list item for the electronic gearbox control if it is assumed that for this subsystem there is a customer complaint, in the form of emergency gearbox operation, during which no gear change is possible, and a fault code relating to the solenoid valves. In a diagnostic entry test, the diagnostic execution stage 1 tests which subareas of the "electronic gearbox control" subsystem could be a cause for the fault code and the complaint. Owing to the presence of the fault code and of the complaint, the "emergency gearbox operation - no gear change" subarea is marked as suspicious.

The following test in accordance with the diagnostic program prepared by the diagnostic sequence preparation stage 2 then identifies a line break in a specific solenoid valve circuit as a cause for the complaint and the presence of the fault code. By means of further tests, it is determined which defect is causing the break, the electrical plug-in contacts and resistors being tested. During this process, the diagnostic execution stage 1 generates corresponding test instructions on the basis of the fault model contained in the knowledge base of the diagnostic sequence preparation stage 2. During one of the resistance measurements, it is detected that the break in the line set is localized, and the service technician receives a corresponding repair instruction. A verification measurement which ensures that the fault is actually eliminated is carried out according to the repair instruction. After successful verification, the diagnostic sequence returns to the detailed check list, according to which further faults can be diagnosed, if appropriate.

The dialogue between the service technician and diagnostic execution stage during the diagnosis takes place via a monitor on which in each case a suitable portion of the entire system is illustrated. On the screen display, a distinction is made, by means of different coloured marking, between components which have already been detected as free of faults and components which are still undiagnosed. The selection and structure of the optimum graphics for the respective part of the diagnosis are based on the stored knowledge base, specifically on the function model, which provides variability by virtue of the possibility of always representing precisely the relevant functional relationships and components in the best way at the respective diagnostic time, which variability cannot otherwise be realized, for example in using of permanently stored graphics for the various system components. Thus, a selection, corresponding as well as possible to a progressive fault localization, of screen displays which progress successively to the smallest function units is obtained.

It becomes apparent that the fault diagnostic device according to the invention is capable of realizing, with relatively little outlay, largely automated and objectivized fault diagnostic sequences, and it is self-evident that such a fault diagnostic device is suitable not only for vehicles, but also for any other desired modular technical systems.

Claims

1. A computer-aided fault diagnostic device for a complex technical system having a plurality of functions to be diagnosed, having

- a diagnostic sequence preparation stage in which a knowledge base is stored which contains a structure model relating to the hierarchical structure of the technical system composed of individual subsystems, a function model relating to the functional relationships between the individual subsystems and a fault model which determines the diagnostic sequence is automatically produced from the structure model and the function model and represents the relationships between fault causes and their effects as well as suitable test sequences and repairs, and
- a diagnostic execution stage for the interactive execution of fault diagnostics using the diagnostic sequence program prepared by the diagnostic sequence preparation stage,

wherein

- the fault model is based on a base fault model which is produced automatically by the diagnostic sequence preparation stage from the structure model and the function model, and for each knowledge base module which is assigned to a respective subsystem it derives precisely one fault model root object, for each associated, hierarchically highest-ranking function area in the function model it derives a fault object which is hierarchically subordinate to the associated fault model root object, for each associated, hierarchically subordinate function area in the function model it derives a fault object which is hierarchically subordinate to the fault object of the hierarchically superordinate function area, and for each associated sub-function area which is formed by opening interfaces in accordance with a precedence list which is produced it derives a fault object which is hierarchically subordinate to the fault object of the hierarchically superordinate function area or sub-function area.

2. A computer-aided fault diagnostic device according to Claim 1, further including an evaluation stage which evaluates the diagnostic sequence protocols of the diagnostic execution stage and supplies knowledge-base-related information for the diagnostic sequence preparation stage.

3. A computer-aided fault diagnostic device according to Claim 1 or 2, wherein, in order to execute a knowledge-base-controlled diagnostic sequence during which initially a short test for interrogating the control units present and for reading out data which relate to diagnosis, in particular fault codes stored in fault memories, is executed, then a check list is produced, subsequently a diagnostic entry test for marking individual areas of a subsystem, given by the check list, as a potential cause of faults is executed and a detailed check list is produced as a function of the result of this test, according to which detailed check list the actual fault search procedure is executed with reference to respective test instructions and, when a fault is detected, a repair instruction is prepared and a subsequent verification test is optionally executed.

4. A computer-aided fault diagnostic device according to Claim 3, wherein the data which relate to diagnosis comprises fault codes stored in fault memories.

5. A computer-aided fault diagnostic device according to any one of Claims 1 to 4, wherein, in the base fault model produced automatically by the diagnostic sequence preparation stage from the structure model and the function

model, a respective fault object is assigned to the interfaces themselves.

6. A computer-aided fault diagnostic device for a complex technical system, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

Amendments to the claims have been filed as follows

1. A computer-aided fault diagnostic device for a complex technical system having a plurality of functions to be diagnosed, having

- a diagnostic sequence preparation stage in which a knowledge base is stored, which base contains a structure model relating to the hierarchical structure of the technical system composed of individual subsystems, a function model relating to the functional relationships between the individual subsystems, and which base contains a fault model which determines the diagnostic sequence and which fault model is automatically produced from the structure model and the function model and represents the relationships between fault causes and their effects as well as suitable test sequences and repairs, and
- a diagnostic execution stage for the interactive execution of fault diagnostics using the diagnostic sequence program prepared by the diagnostic sequence preparation stage,

wherein

- the fault model is based on a base fault model which is produced automatically by the diagnostic sequence preparation stage from the structure model and the function model, and for each knowledge base module which is assigned to a respective subsystem it derives precisely one fault model root object, for each associated, hierarchically highest-ranking function area in the function model it derives a fault object which is hierarchically subordinate to the associated fault model root object, for each associated, hierarchically subordinate function area in the function model it derives a fault object which is hierarchically subordinate to the fault object of the hierarchically superordinate function area, and for each associated sub-function area which is formed by opening interfaces in accordance with a precedence list which is produced it derives a fault object which is hierarchically subordinate to the fault object of the hierarchically superordinate function area or sub-function area.

2. A computer-aided fault diagnostic device according to Claim 1, further including an evaluation stage which evaluates the diagnostic sequence protocols of the diagnostic execution stage and supplies knowledge-base-related information for the diagnostic sequence preparation stage.

3. A computer-aided fault diagnostic device according to Claim 1 or 2, wherein, in order to execute a knowledge-base-controlled diagnostic sequence during which initially a short test for interrogating the control units present and for reading out data which relate to diagnosis, in particular fault codes stored in fault memories, is executed, then a check list is produced, subsequently a diagnostic entry test for marking individual areas of a subsystem, given by the check list, as a potential cause of faults is executed and a detailed check list is produced as a function of the result of this test, according to which detailed check list the actual fault search procedure is executed with reference to respective test instructions and, when a fault is detected, a repair instruction is prepared and a subsequent verification test is optionally executed.

4. A computer-aided fault diagnostic device according to Claim 3, wherein the data which relate to diagnosis comprises fault codes stored in fault memories.

5. A computer-aided fault diagnostic device according to any one of Claims 1 to 4, wherein, in the base fault model produced automatically by the diagnostic sequence preparation stage from the structure model and the function

model, a respective fault object is assigned to the interfaces themselves.

6. A computer-aided fault diagnostic device for a complex technical system, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

The Patent Office

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Application No:	GB 9613224.6	**Examiner:**	Paul Nicholls
Claims searched:	1 - 6	**Date of search:**	3 September 1996

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G4A (AUB)

Int Cl (Ed.6): G06F 9/44, 15/18, 19/00

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0,364,151 A2 (TEXAS INSTRUMENTS)	-
A	US 5,127,005 A (RICOH)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		