US007387183B2

(12) **United States Patent**
Breed et al.

(10) **Patent No.: US 7,387,183 B2**
(45) **Date of Patent: *Jun. 17, 2008**

(54) **WEIGHT MEASURING SYSTEMS AND METHODS FOR VEHICLES**

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(73) Assignee: **Automotive Technologies International, Inc.**, Denville, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 165 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/010,819**

(22) Filed: **Dec. 13, 2004**

(65) **Prior Publication Data**

US 2005/0156457 A1 Jul. 21, 2005

Related U.S. Application Data

(60) Division of application No. 10/733,957, filed on Dec. 11, 2003, now Pat. No. 7,243,945, and a continuation-in-part of application No. 10/227,781, filed on Aug. 26, 2002, now Pat. No. 6,792,342, which is a continuation-in-part of application No. 10/061,016, filed on Jan. 30, 2002, now Pat. No. 6,833,516, which is a continuation-in-part of application No. 09/901,879, filed on Jul. 9, 2001, now Pat. No. 6,555,766, which is a continuation-in-part of application No. 09/849,559, filed on May 4, 2001, now Pat. No. 6,689,962, and a continuation-in-part of application No. 09/500,346, filed on Feb. 8, 2000, now Pat. No. 6,442,504, which is a continuation-in-part of application No. 09/193,209, filed on Nov. 17, 1998, now Pat. No. 6,242,701, which is a continuation-in-part of application No. 09/128,490, filed on Aug. 4, 1998, now Pat. No. 6,078,854, and a continuation-in-part of application No. 08/970,822, filed on Nov. 14, 1997, now Pat. No. 6,081,757, which is a continuation-in-part of application No. 08/474,783, filed on Jun. 7, 1995, now Pat. No. 5,822,707.

(51) **Int. Cl.**
B60D 1/28 (2006.01)
B60K 28/00 (2006.01)
B60R 21/00 (2006.01)

(52) **U.S. Cl.** **180/271**; 180/273; 280/735; 701/45

(58) **Field of Classification Search** 280/735; 180/271, 273, 71; 701/45, 49; 702/173
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,275,975 A 9/1966 King 180/272

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0345806 12/1989

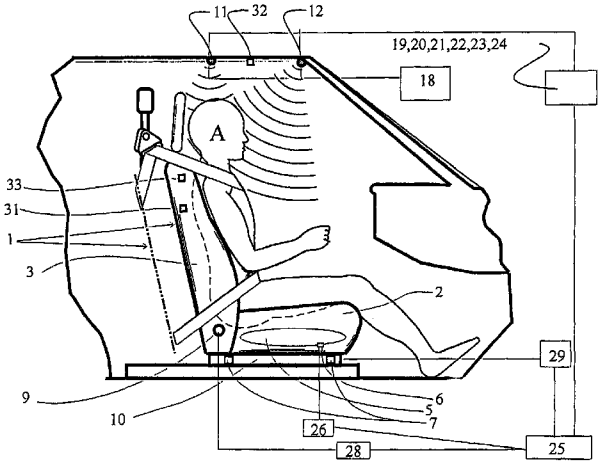
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Primary Examiner—Toan C To
(74) *Attorney, Agent, or Firm*—Brian Roffe

(57) **ABSTRACT**

Method for determining the position of the occupant in a seat having a bottom portion on which the occupant sits and a back portion situated at an angle to the bottom portion including arranging a bladder having at least one chamber in the bottom portion, measuring the pressure in each chamber, and determining the position of the occupant based at least on part on the measured pressure. Pressure may be measured by arranging at least one transducer in association with each chamber. If the bladder comprises a plurality of chambers, each chamber can be arranged at a different location in the bottom portion and the weight distribution of the occupant determined based on the measured pressure in the chambers. In this case, a respective transducer may be arranged in association with each chamber.

11 Claims, 36 Drawing Sheets



U.S. PATENT DOCUMENTS

4,519,652	A		5/1985	Kamijo 180/268
4,625,329	A		11/1986	Ishikawa 382/104
4,639,872	A		1/1987	McHale et al. 364/463
4,645,233	A		2/1987	Bruse et al. 280/753
4,698,571	A		10/1987	Mizuta et al. 318/466
4,811,226	A		3/1989	Shinohara 318/466
4,907,153	A		3/1990	Brodsky 364/424.05
4,957,286	A		9/1990	Persons, II et al. 272/73
5,008,946	A		4/1991	Ando 180/167
5,071,160	A		12/1991	White et al. 280/735
5,074,583	A		12/1991	Fujita 280/735
5,086,652	A		2/1992	Kropp 73/767
5,090,493	A		2/1992	Bergan et al. 177/211
5,118,134	A		6/1992	Mattes 280/735
5,125,686	A		6/1992	Yano 280/801.2
5,155,685	A		10/1992	Kishi et al. 364/424.05
5,161,820	A		11/1992	Vollmer 280/730
5,222,399	A		6/1993	Kropp 73/862.68
5,232,243	A		8/1993	Blackburn et al. 280/735
5,254,924	A		10/1993	Ogasawara 364/424.05
5,330,226	A		7/1994	Gentry et al. 280/735
5,377,108	A		12/1994	Nishio 701/45
5,413,378	A		5/1995	Steffens, Jr. et al. 280/735
5,439,249	A		8/1995	Steffens, Jr. et al. 280/735
5,454,591	A		10/1995	Mazur et al. 280/735
5,474,327	A		12/1995	Schousek 280/735
5,531,472	A		7/1996	Semchena et al. 280/735
5,573,269	A		11/1996	Gentry et al. 280/735
5,583,771	A		12/1996	Lynch et al. 701/45
5,653,462	A		8/1997	Breed et al. 280/735
5,670,853	A		9/1997	Bauer 318/286
5,691,693	A		11/1997	Kithil 340/439
5,694,320	A		12/1997	Breed 364/424.055
5,702,123	A		12/1997	Takahashi et al. 280/735
5,714,695	A		2/1998	Bruns 177/211
5,748,473	A		5/1998	Breed et al. 364/424.055
5,785,347	A		7/1998	Adolph et al. 280/735
5,802,479	A		9/1998	Kithil et al. 701/45
5,822,707	A		10/1998	Breed et al. 701/49
5,829,782	A		11/1998	Breed et al. 280/735
5,844,486	A		12/1998	Kithil et al. 340/573
5,848,802	A		12/1998	Breed et al. 280/735
5,877,677	A		3/1999	Fleming et al. 340/436
5,904,219	A	*	5/1999	Anahid et al. 180/273
5,918,696	A		7/1999	Van Voorhies 180/273
5,927,427	A	*	7/1999	Sewell et al. 180/273
5,942,695	A		8/1999	Verma et al. 73/768
5,943,295	A		8/1999	Varga et al. 180/273
5,957,491	A		9/1999	Cech et al. 280/735
5,984,349	A		11/1999	Van Voorhies 280/735
5,991,676	A		11/1999	Podoloff et al. 701/45
6,015,163	A		1/2000	Langford et al. 280/735
6,039,344	A		3/2000	Mehney et al. 280/735
6,056,079	A		5/2000	Cech et al. 180/273
6,069,325	A		5/2000	Aoki 177/136
6,078,854	A		6/2000	Breed et al. 701/49
6,081,757	A		6/2000	Breed et al. 701/45
6,087,598	A		7/2000	Munch 177/144
6,101,436	A		8/2000	Fortune et al. 701/45
6,104,100	A		8/2000	Neuman 307/10.1
6,161,891	A		12/2000	Blakesley 296/65.01
6,218,632	B1		4/2001	McCarthy et al. 177/144
6,231,076	B1		5/2001	Blakesley et al. 280/735
6,240,352	B1		5/2001	McCurdy 701/45
6,253,134	B1		6/2001	Breed et al. 701/49
6,260,879	B1		7/2001	Stanley 280/735
6,330,501	B1	*	12/2001	Breed et al. 701/49
6,345,839	B1		2/2002	Kuboki et al. 280/735
6,442,504	B1	*	8/2002	Breed et al. 702/173
6,555,766	B2		4/2003	Breed et al. 177/144
6,578,871	B2		6/2003	Gray et al. 280/735
6,653,577	B2		11/2003	Breed et al. 177/244
7,243,945	B2	*	7/2007	Breed et al. 280/735

FOREIGN PATENT DOCUMENTS

EP	0152092 A1	8/1995	
EP	0728636 A1	8/1996	
EP	950560	10/1999	..... 177/144
EP	0990565	4/2000	
EP	0721863 B1	5/2000	
GB	2289332	11/1995	..... 280/735
GB	2333070	7/1999	
GB	2340252	2/2000	
JP	3032943	2/1991	
JP	3062699	3/1991	
JP	04-138996	5/1992	
WO	9825112	6/1998	
WO	9830411	7/1998	
WO	0112473	2/2001	
WO	0113076	2/2001	

* cited by examiner

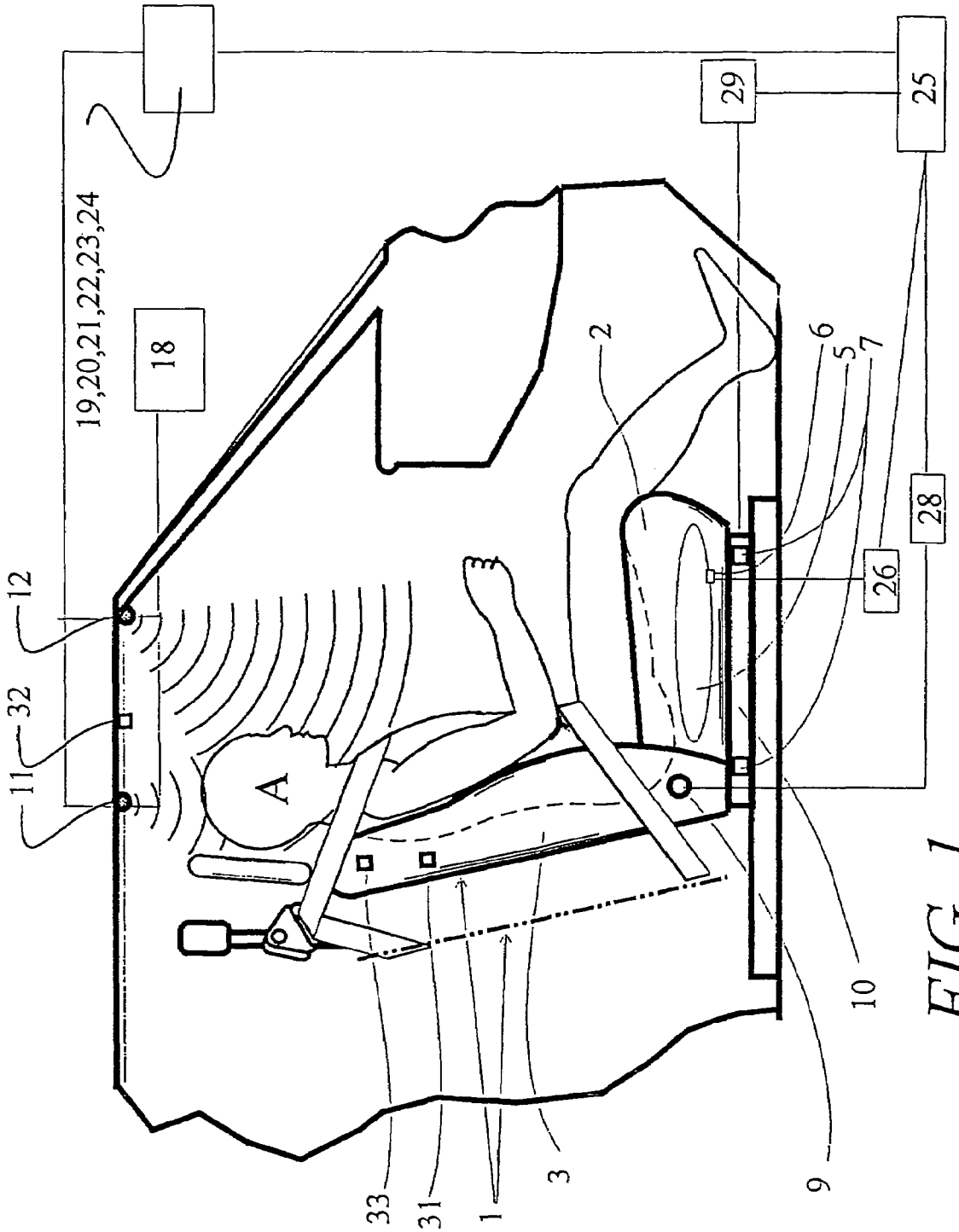


FIG. 1

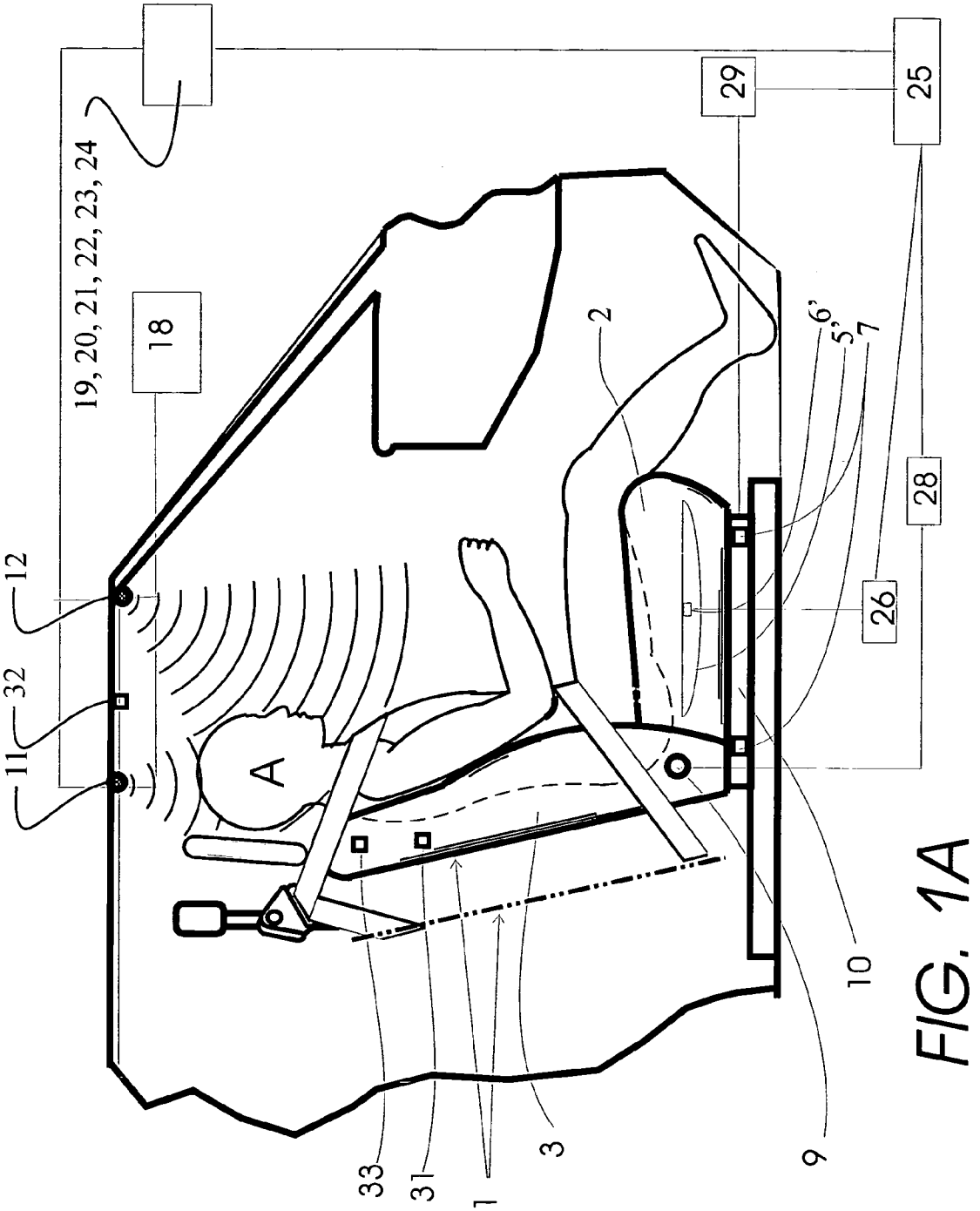


FIG. 1A

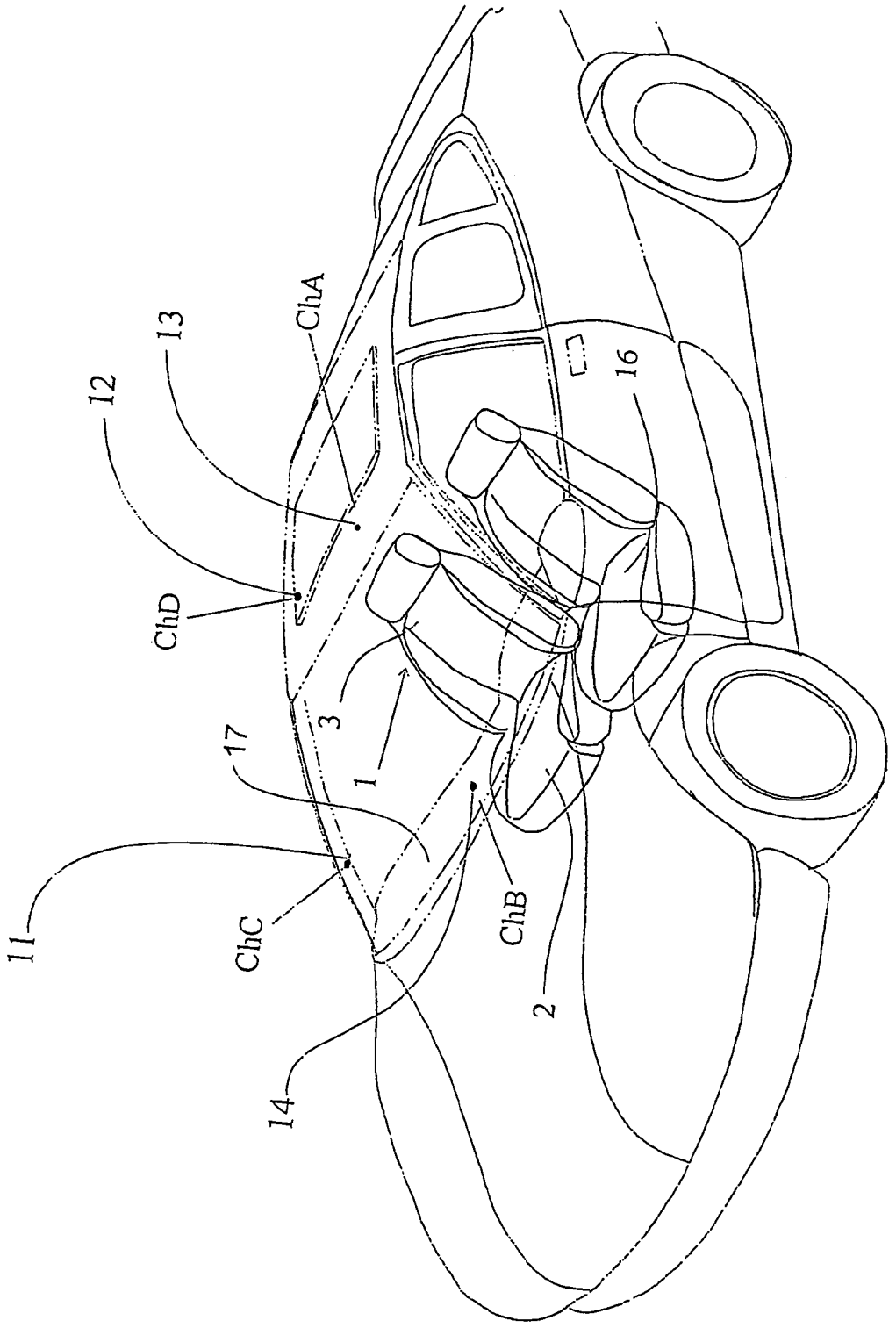


FIG. 2

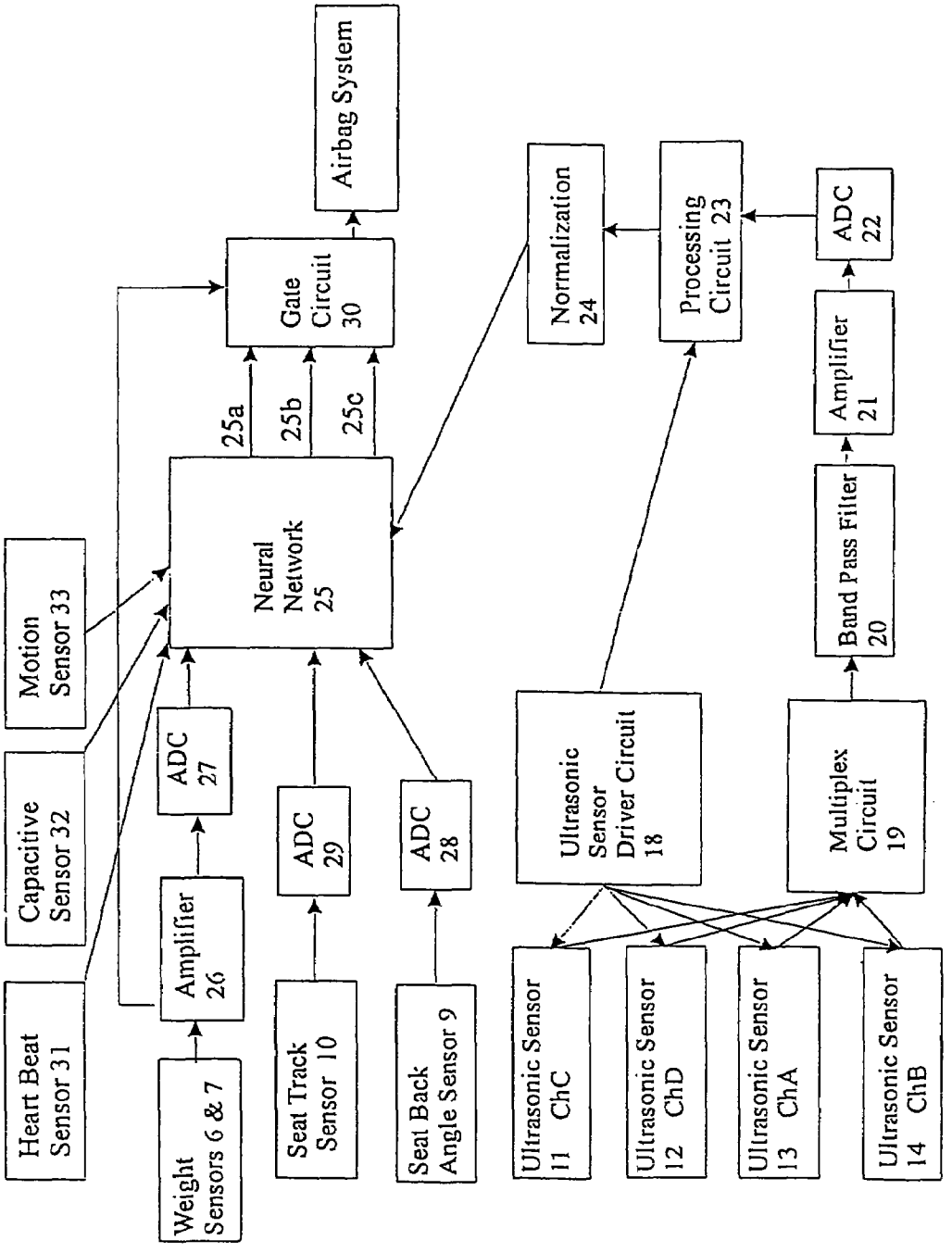

Airbag System
Gate Circuit 30
25a
25b
25c
Neural Network 25
Motion Sensor 33
Capacitive Sensor 32
Heart Beat Sensor 31
Weight Sensors 6 & 7
Amplifier 26
ADC 27
Seat Track Sensor 10
ADC 29
Seat Back Angle Sensor 9
ADC 28
Normalization 24
Processing Circuit 23
ADC 22
Amplifier 21
Band Pass Filter 20
Multiplex Circuit 19
Ultrasonic Sensor Driver Circuit 18
Ultrasonic Sensor 11 ChC
Ultrasonic Sensor 12 ChD
Ultrasonic Sensor 13 ChA
Ultrasonic Sensor 14 ChB

FIG. 3

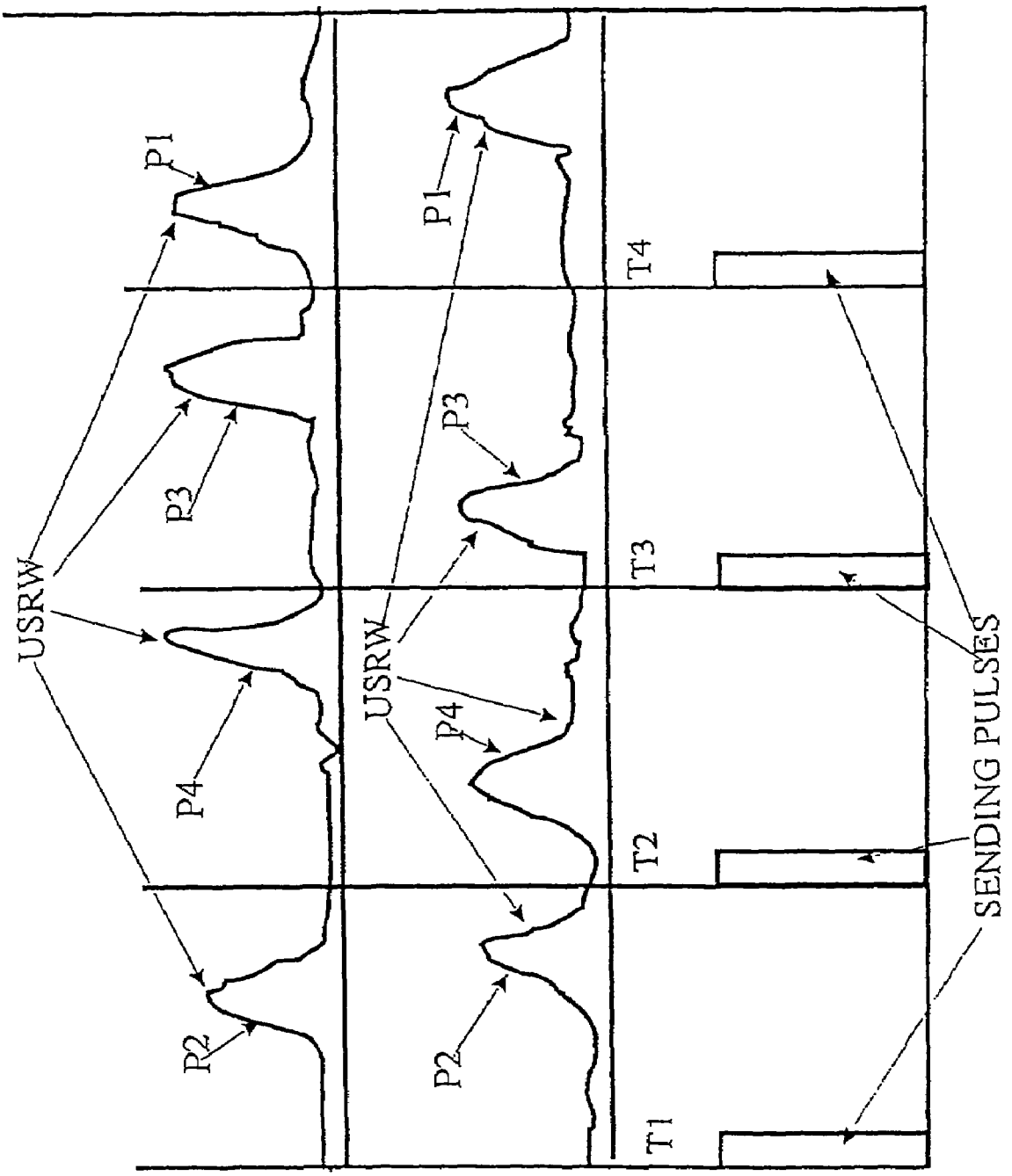


FIG. 4(a)

FIG. 4(b)

FIG. 4(c)

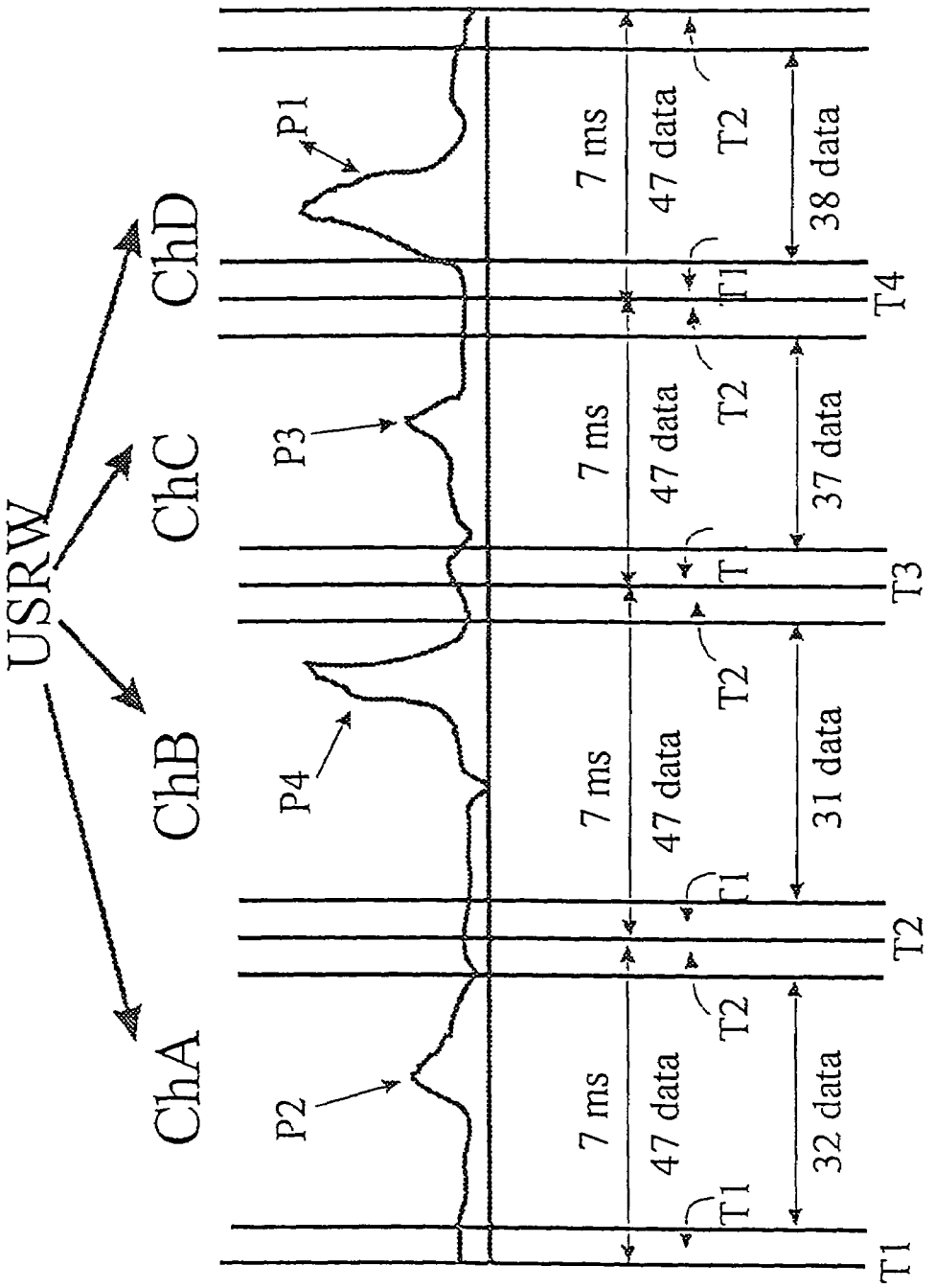

USRW
ChA
ChB
ChC
ChD
P1
P2
P3
P4
7 ms
47 data
T1
T2
T3
T4
32 data
31 data
37 data
38 data

FIG. 5

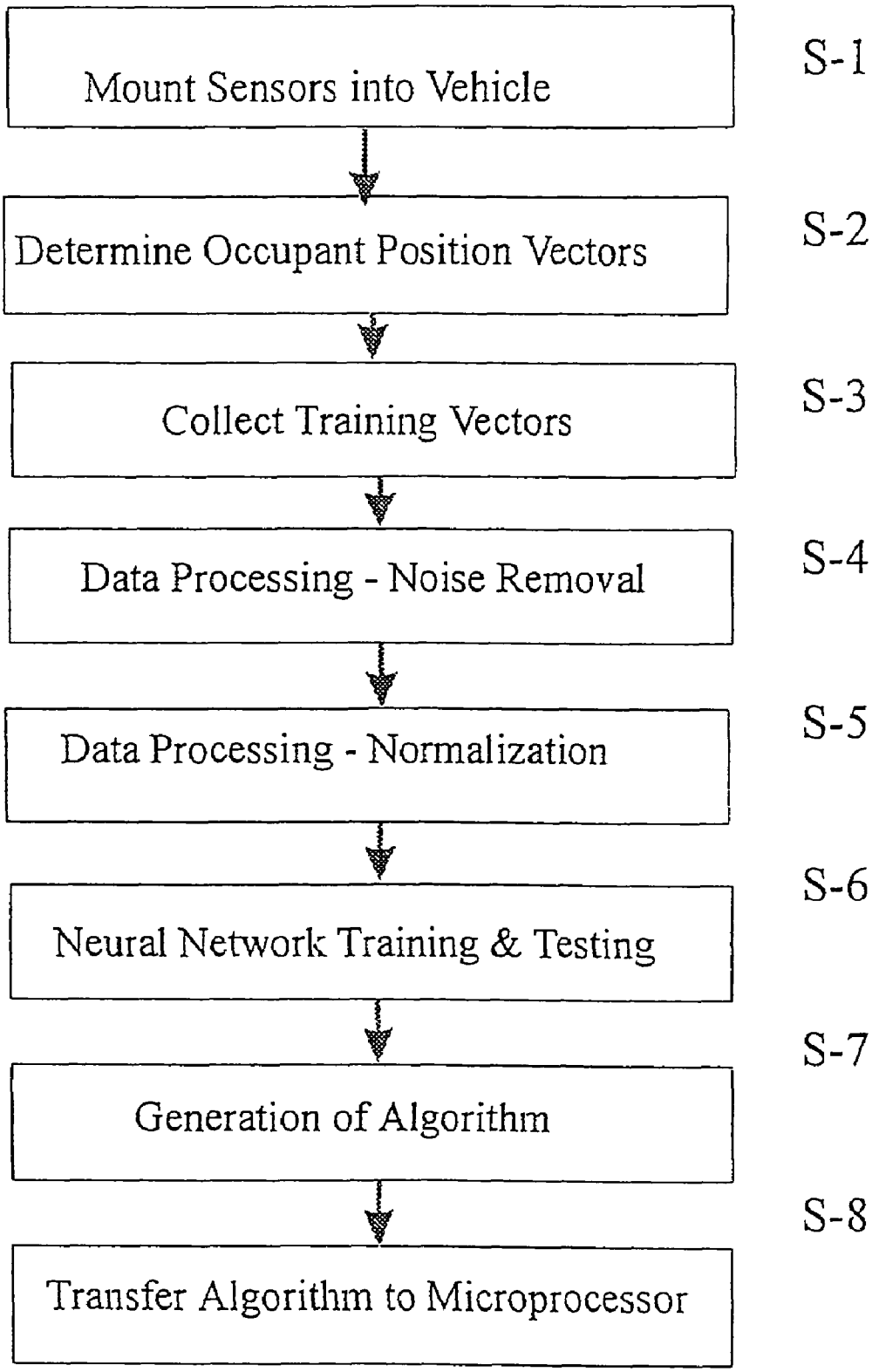

Mount Sensors into Vehicle
S-1
Determine Occupant Position Vectors
S-2
Collect Training Vectors
S-3
Data Processing - Noise Removal
S-4
Data Processing - Normalization
S-5
Neural Network Training & Testing
S-6
Generation of Algorithm
S-7
Transfer Algorithm to Microprocessor
S-8

FIG. 6

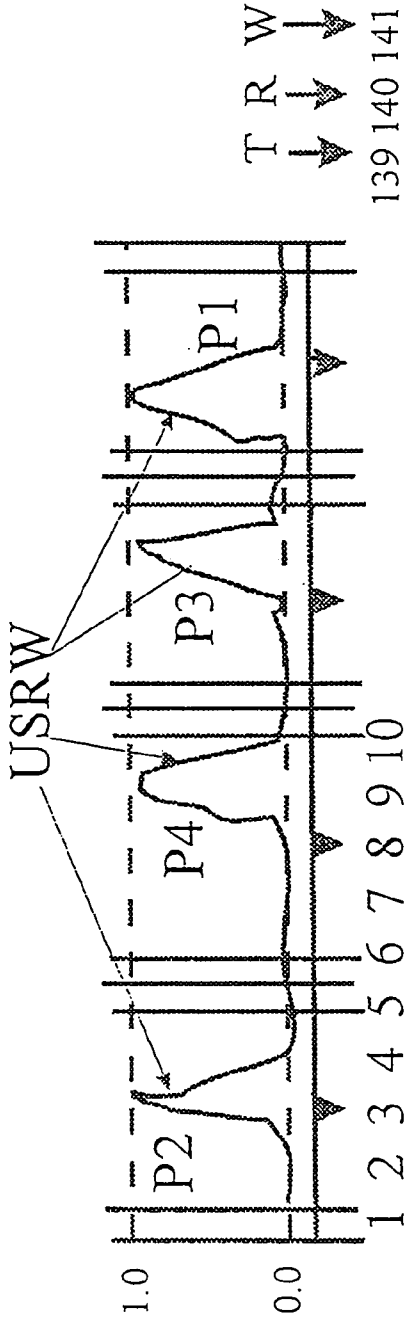

USRW
P1
P2
P3
P4
1.0
0.0
1 2 3 4 5 6 7 8 9 10
139 140 141
T R W

FIG. 7a

INPUT
LAYER 1
LAYER 2
OUTPUT
25
20
3
1 0 0 FFH or FFCS
0 1 0 RFCS or OOPH
0 0 1 VACANT

FIG. 7b

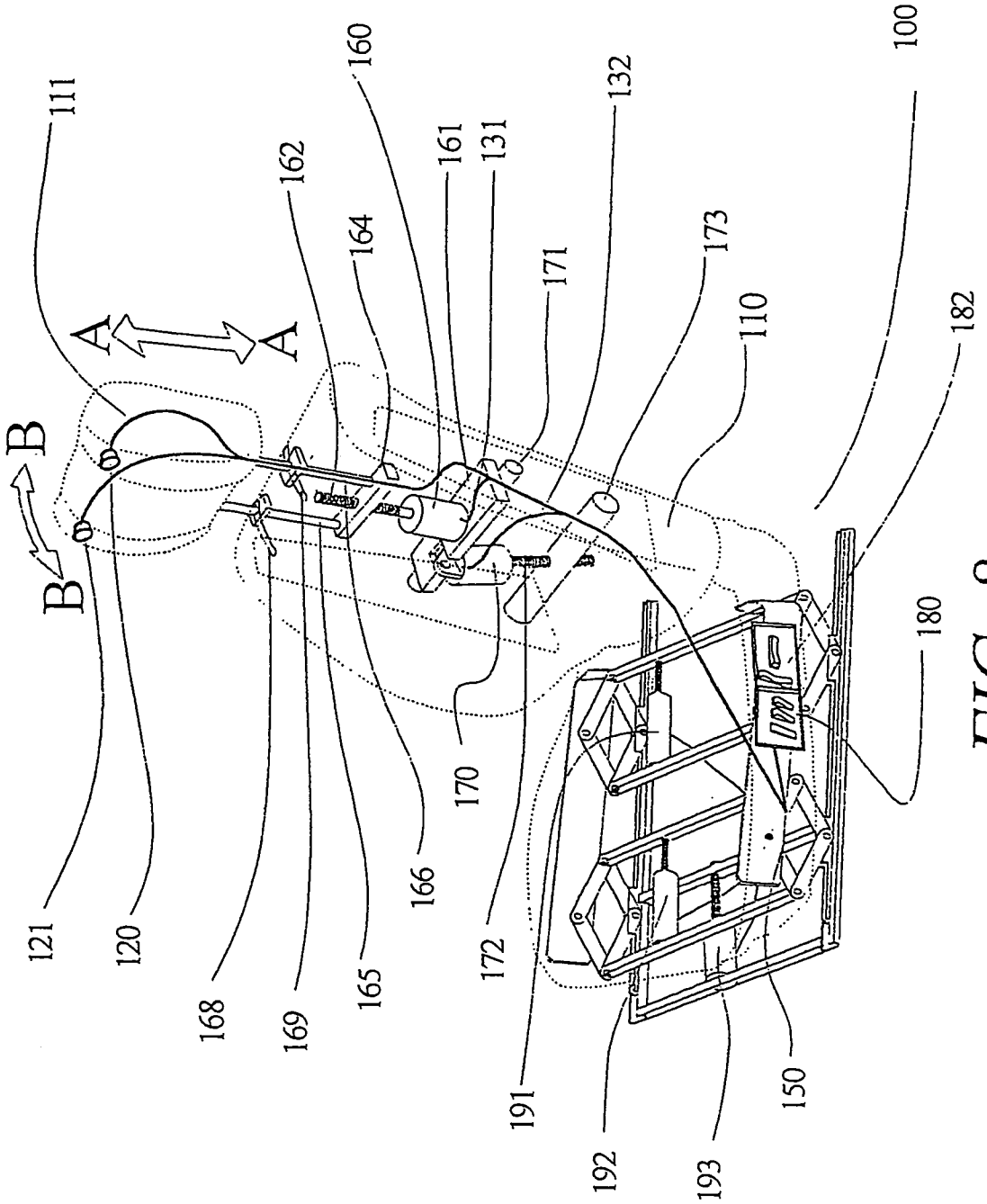

111
160
162
161
131
132
100
164
171
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110
182
A
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193
150

FIG. 8

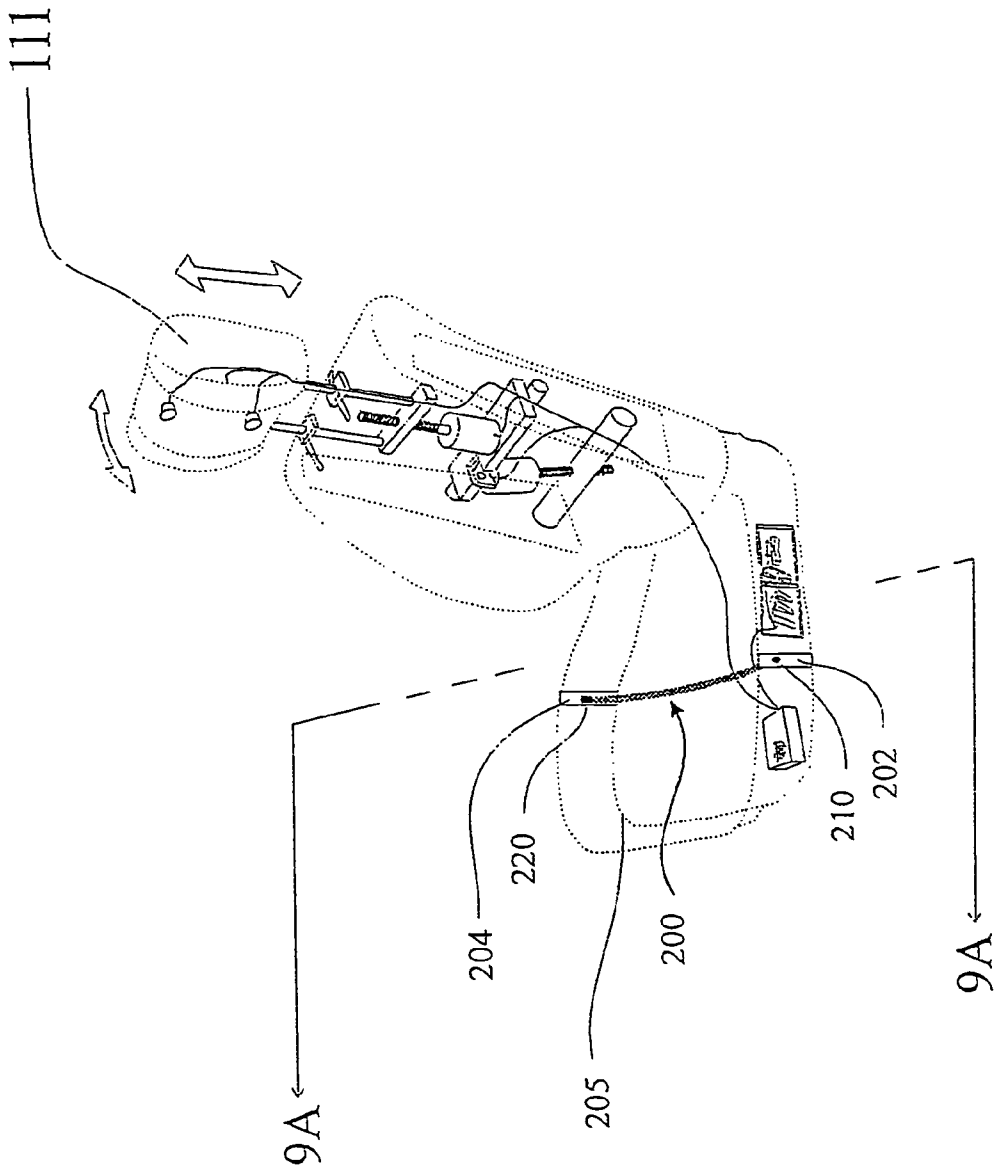


FIG. 9

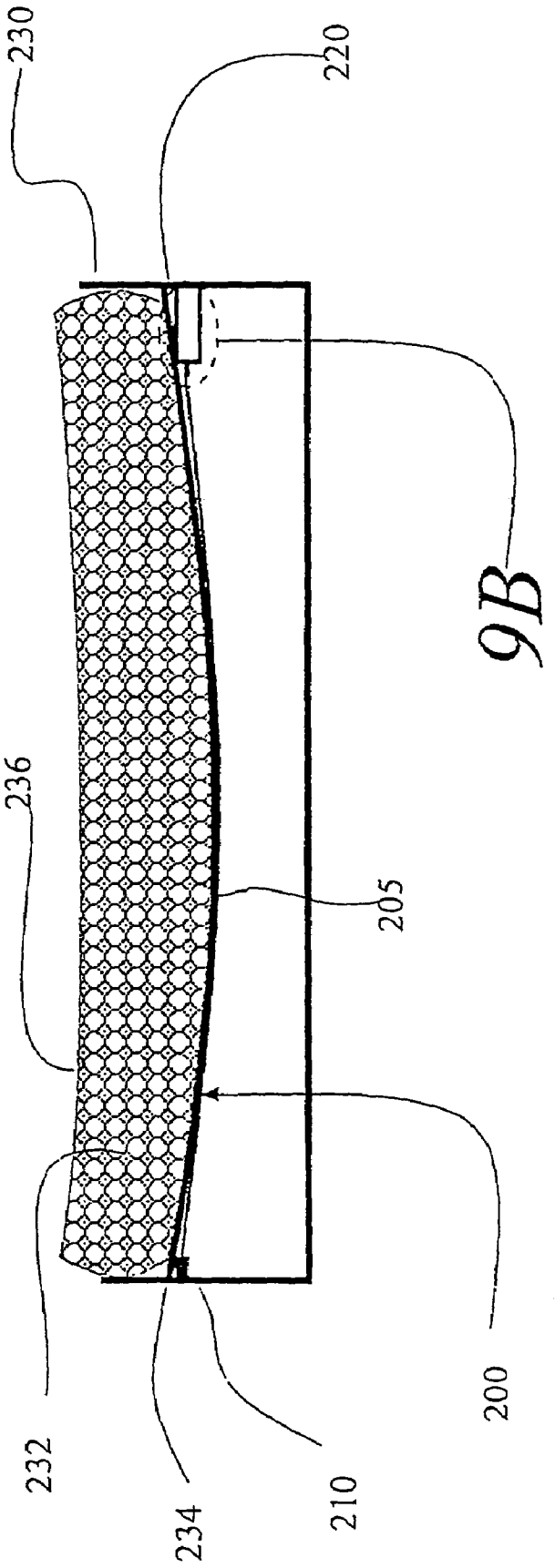


FIG. 9A

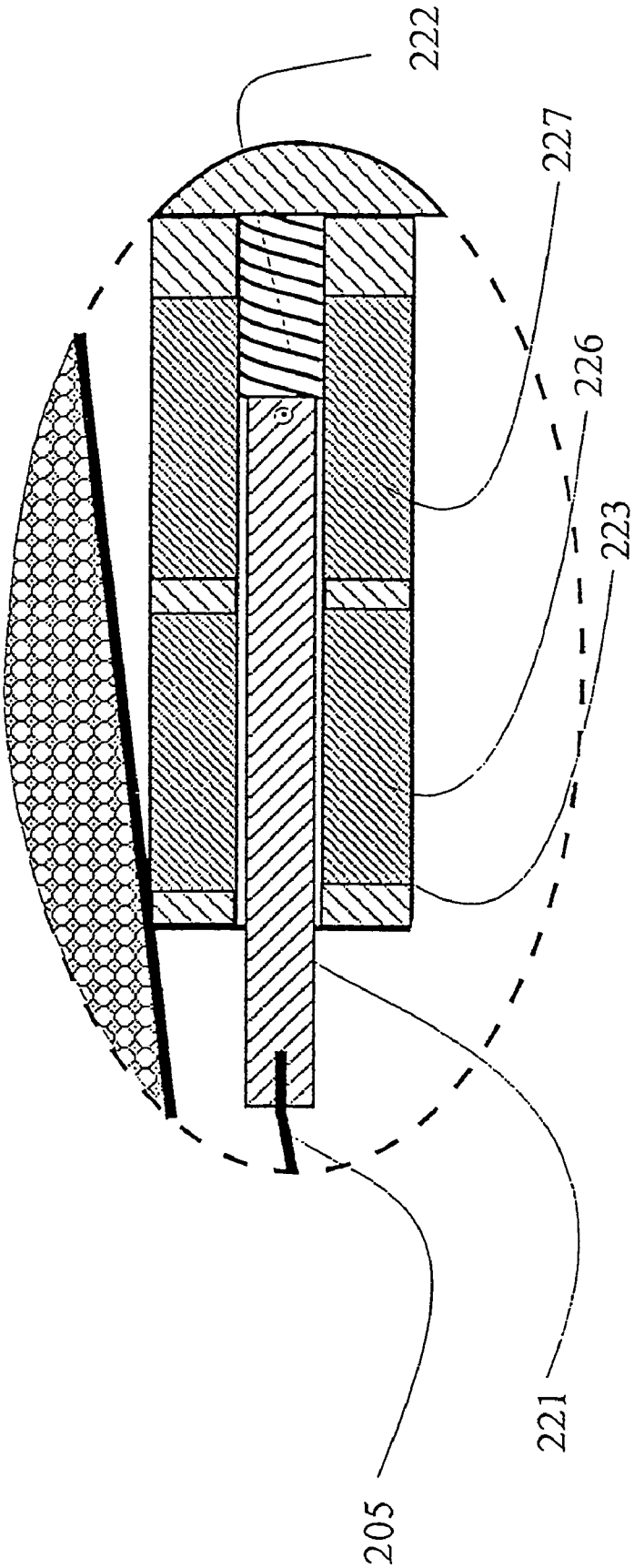


FIG. 9B

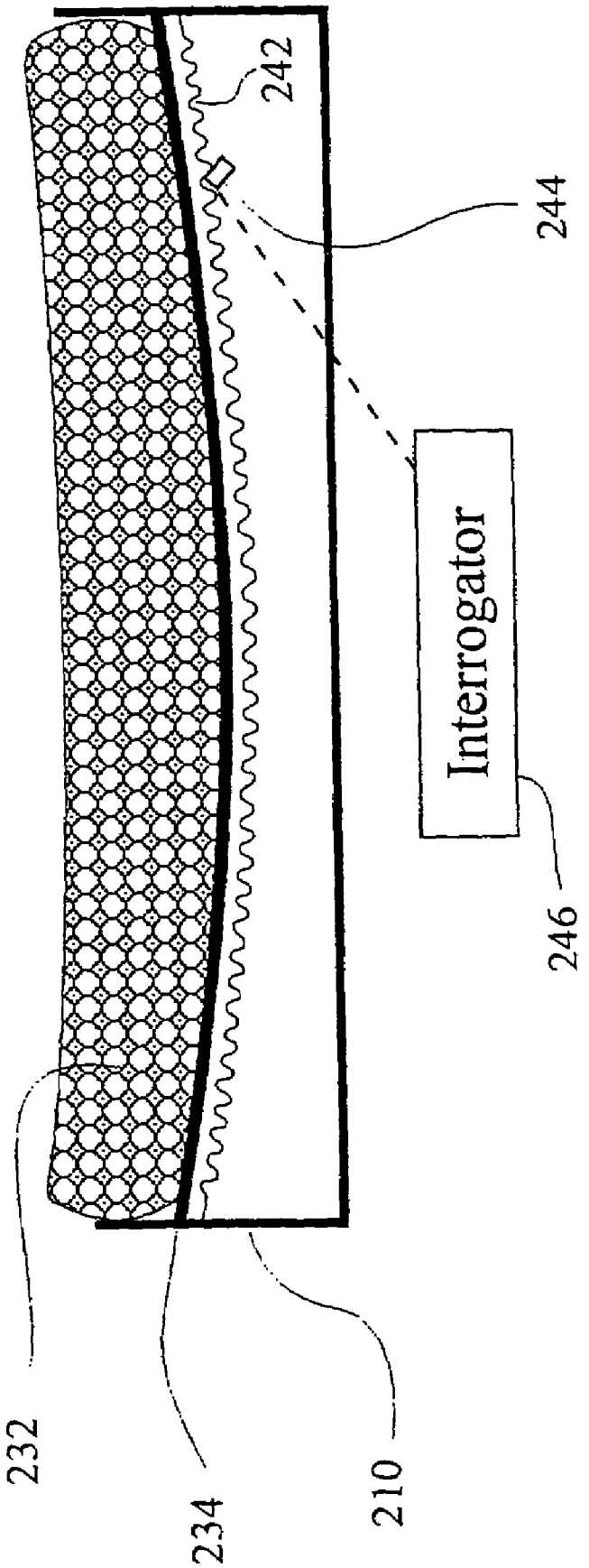


FIG. 9C

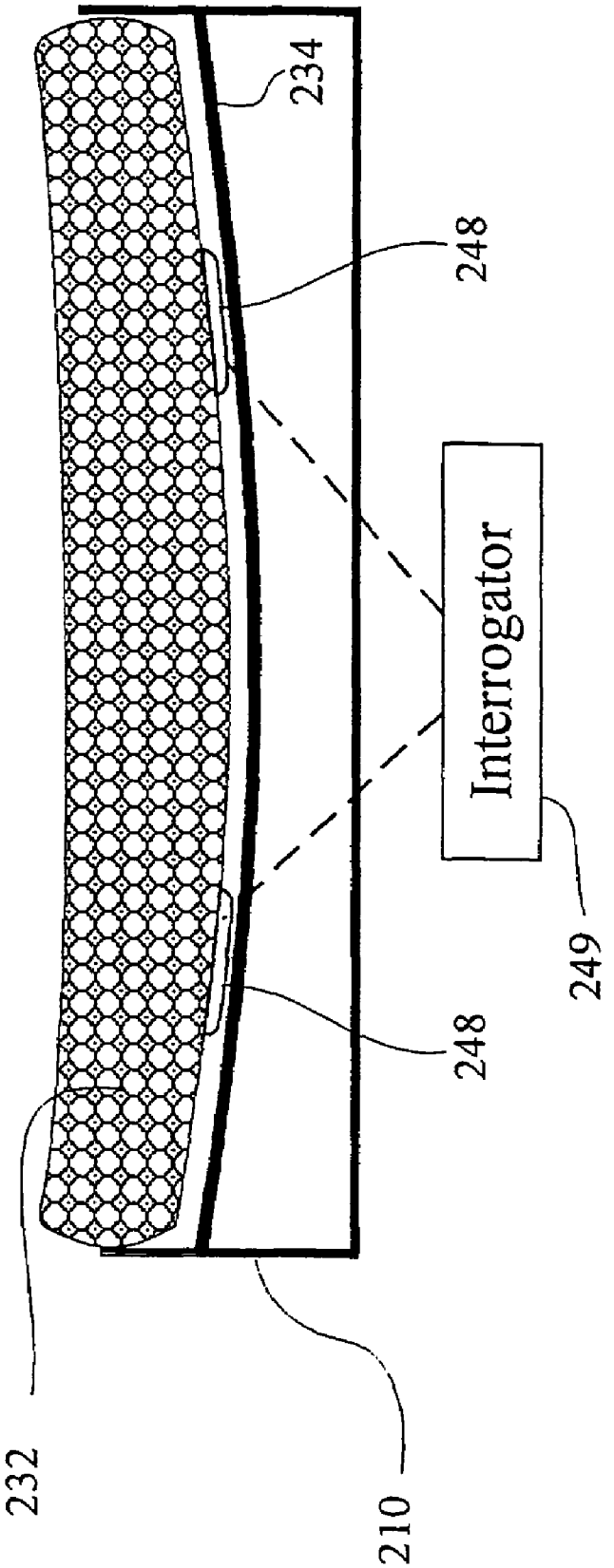


FIG. 9D

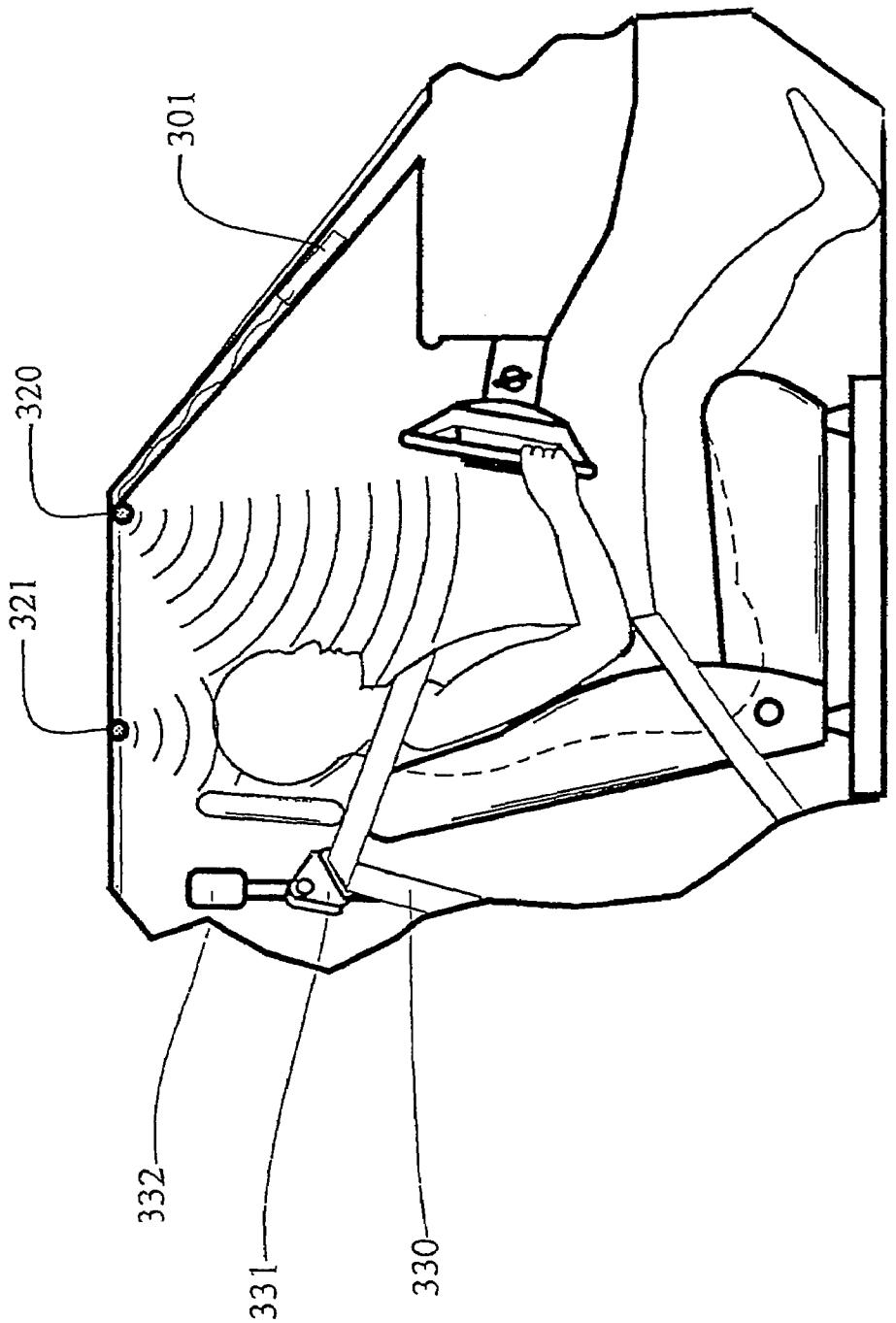


FIG. 10

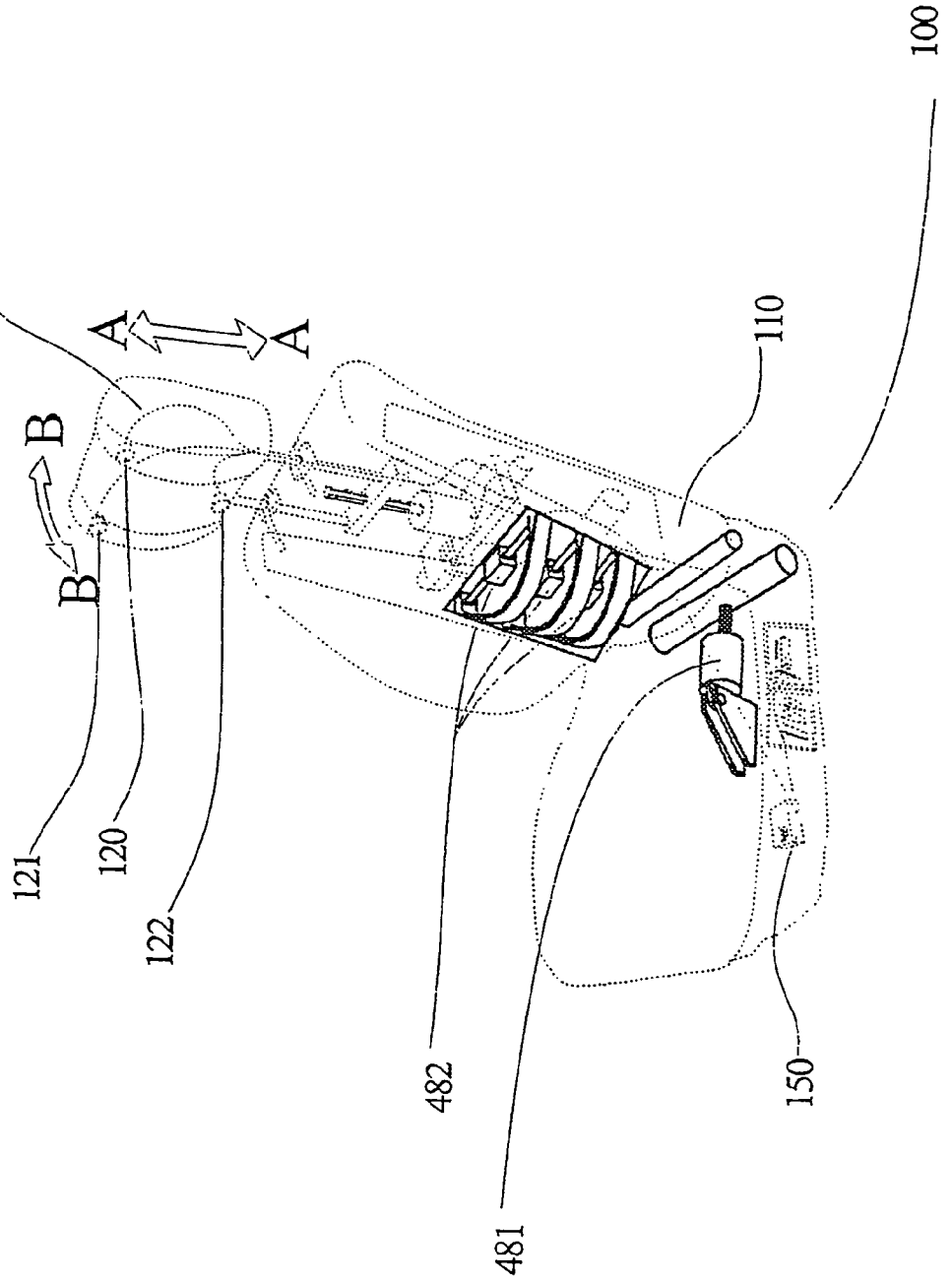


FIG. 11

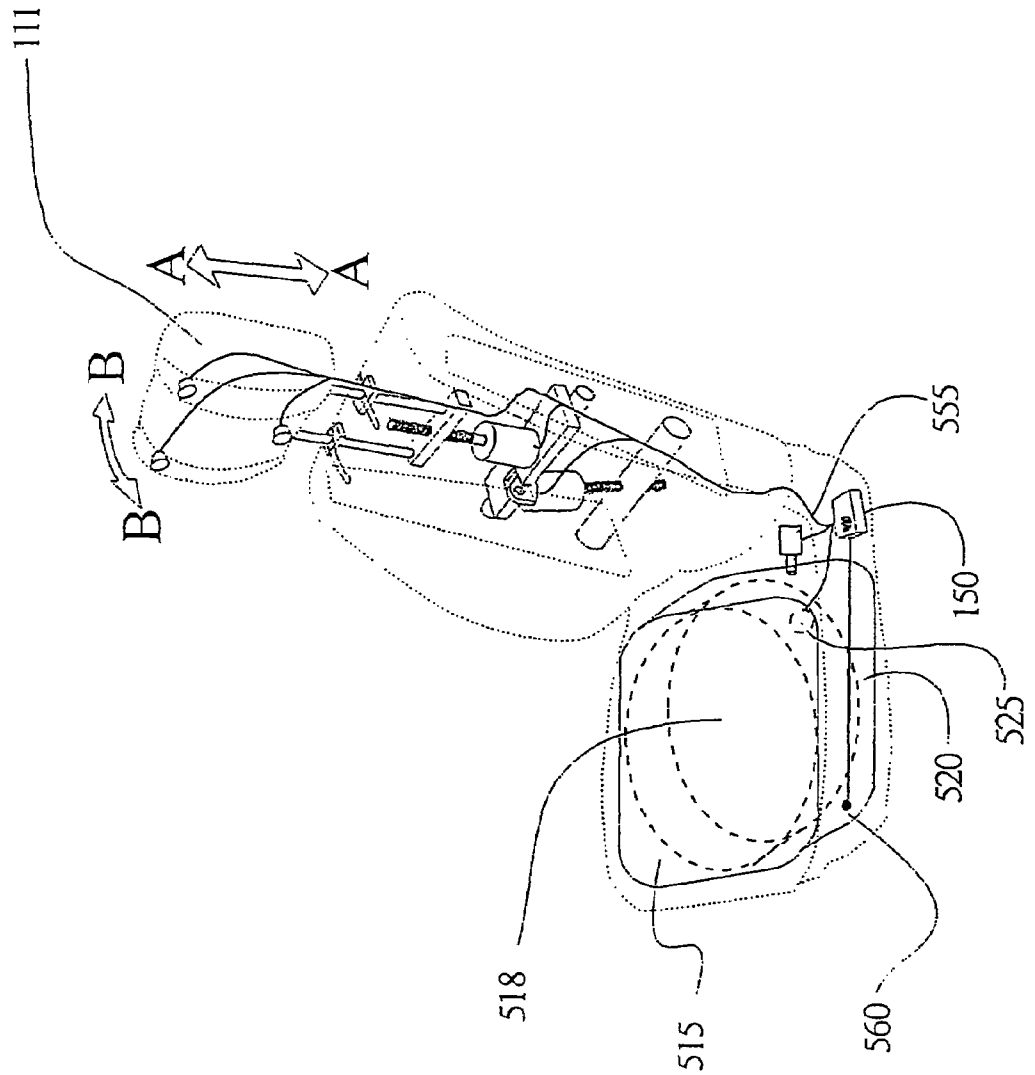


FIG. 12

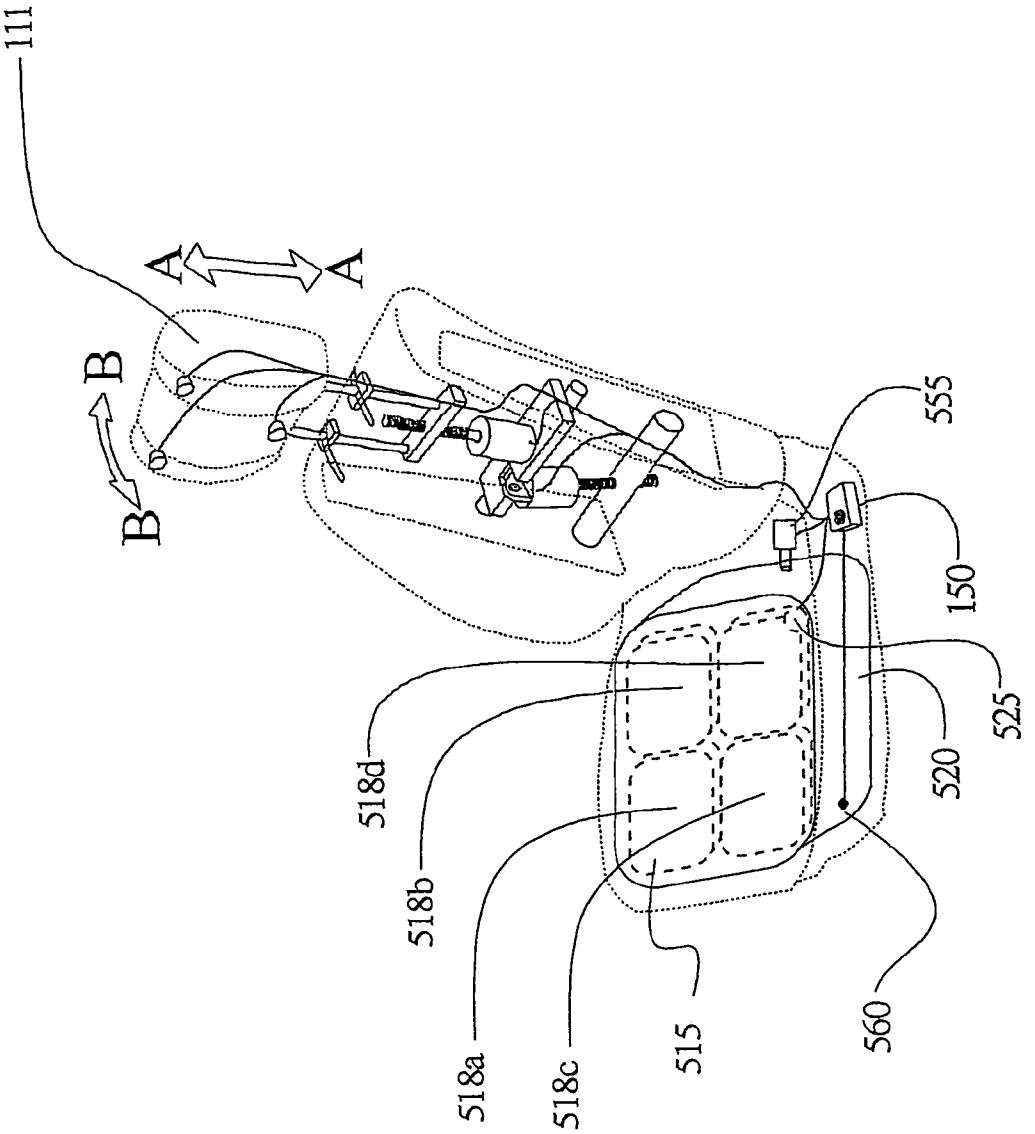


FIG. 12A

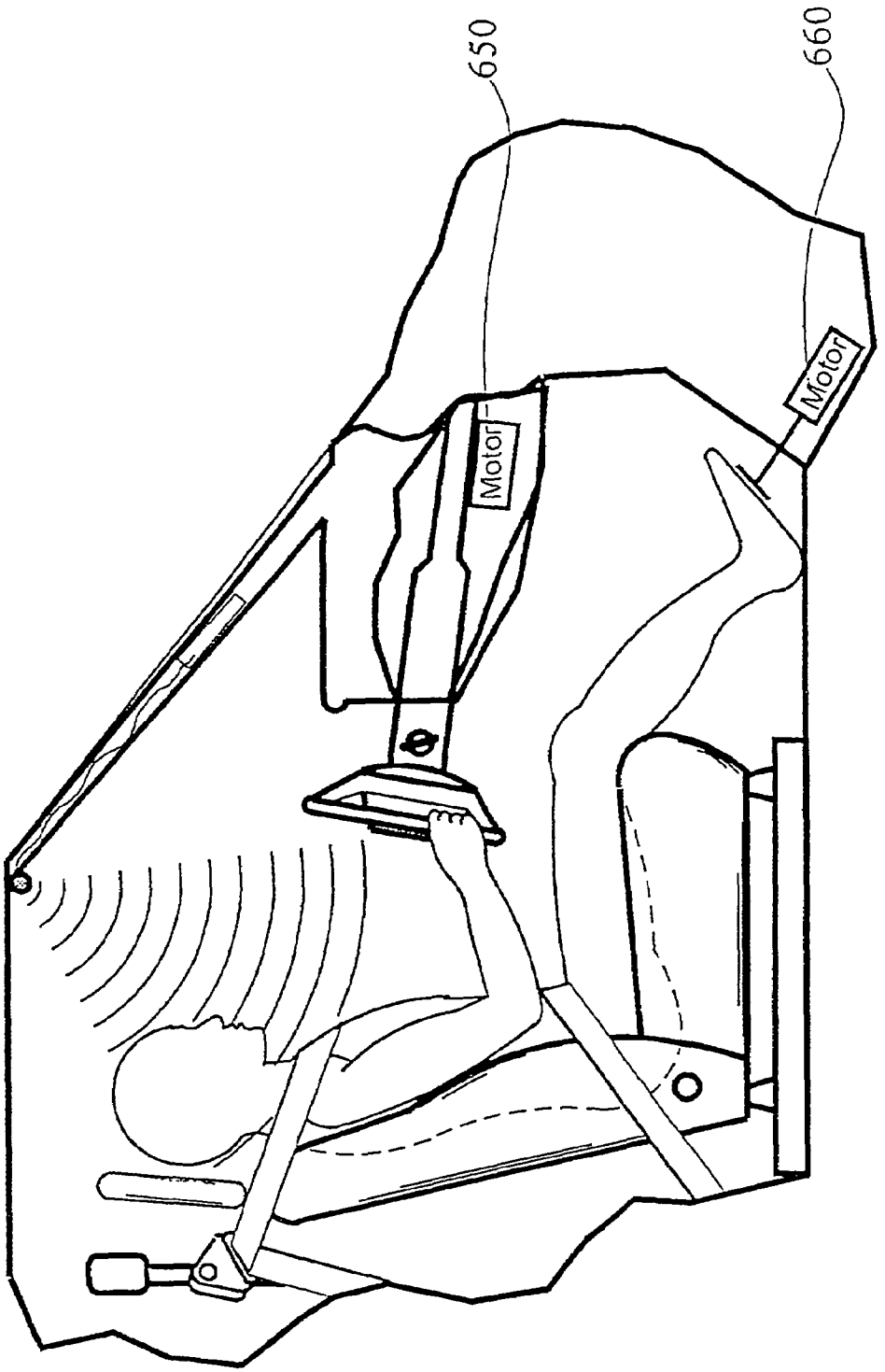


FIG. 13

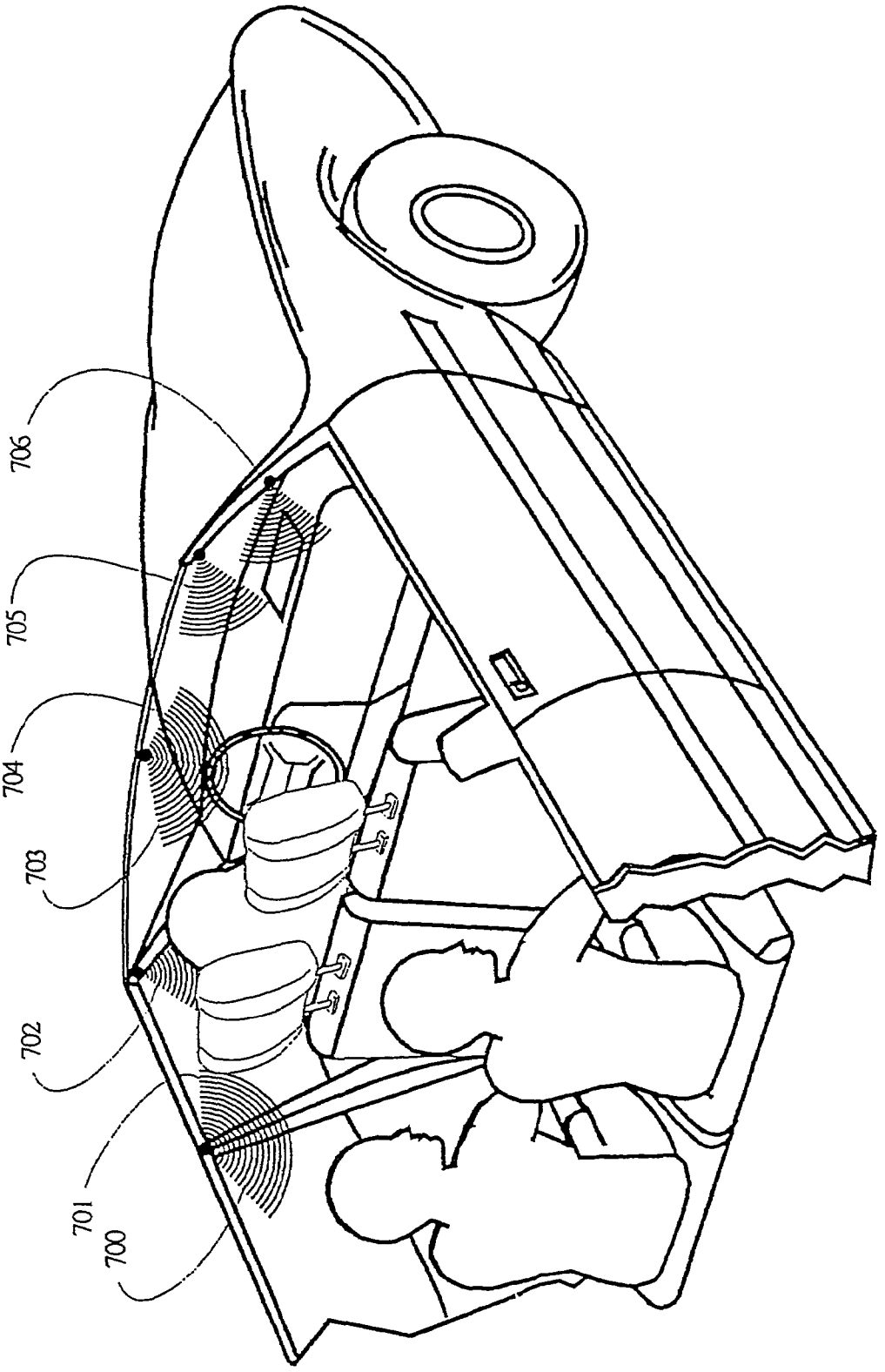


FIG. 14

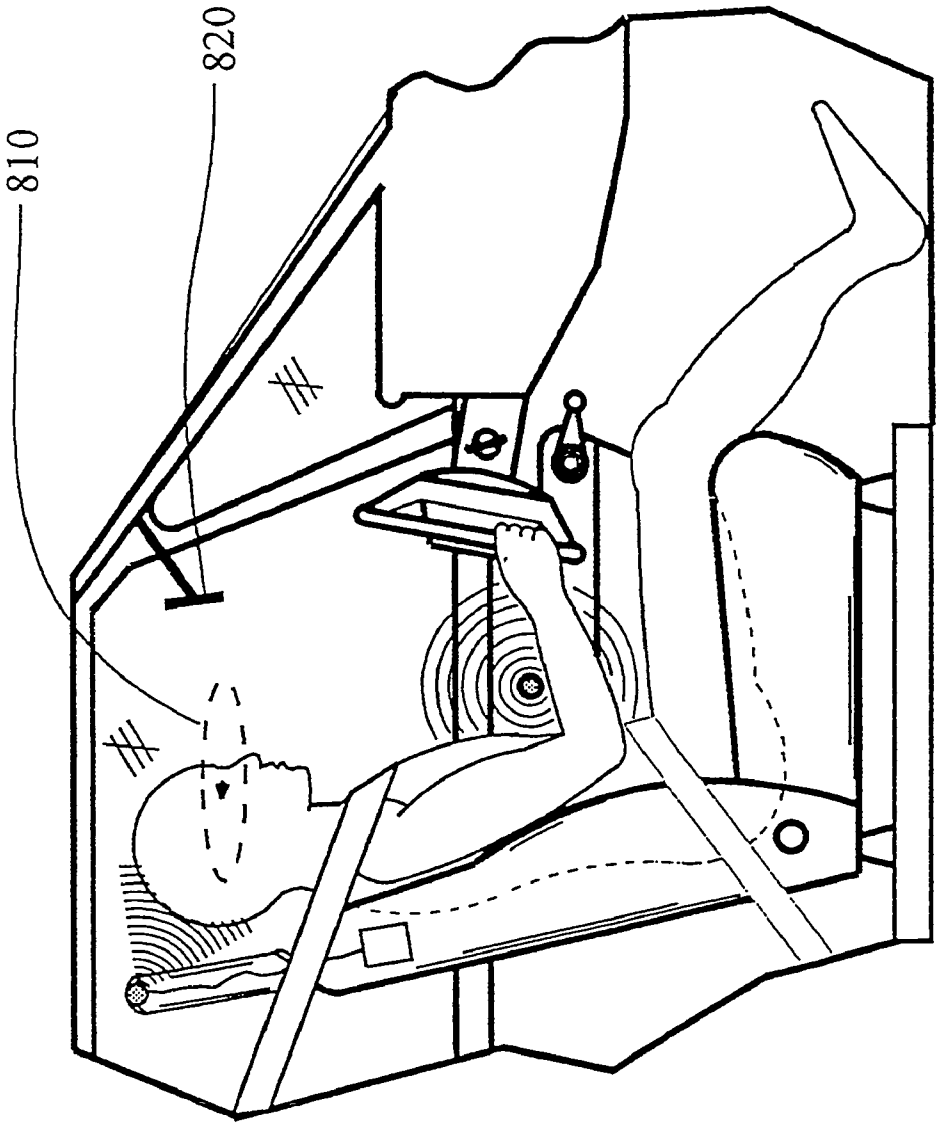


FIG. 15

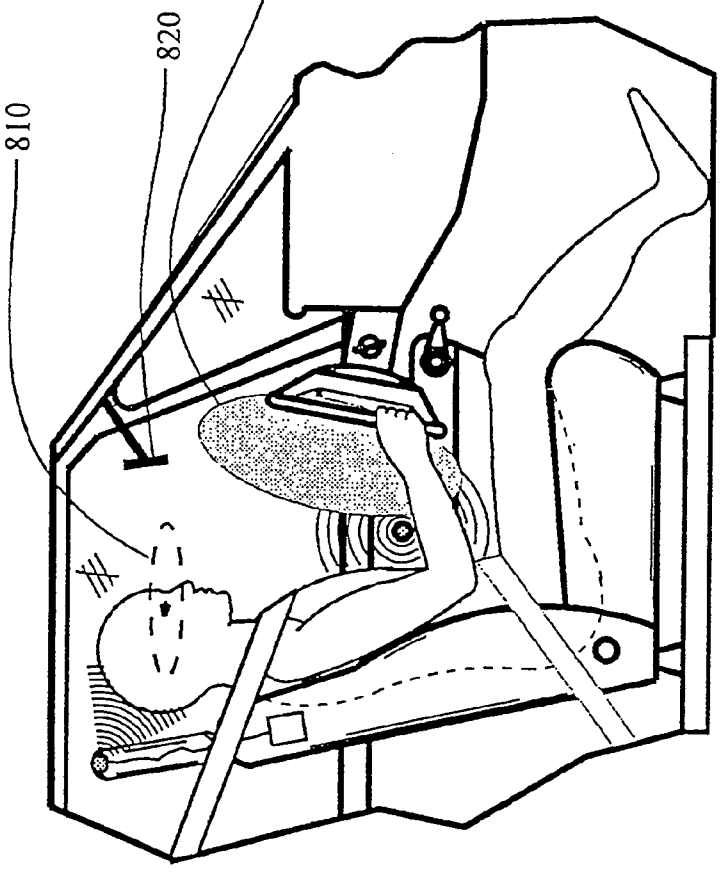


FIG. 16

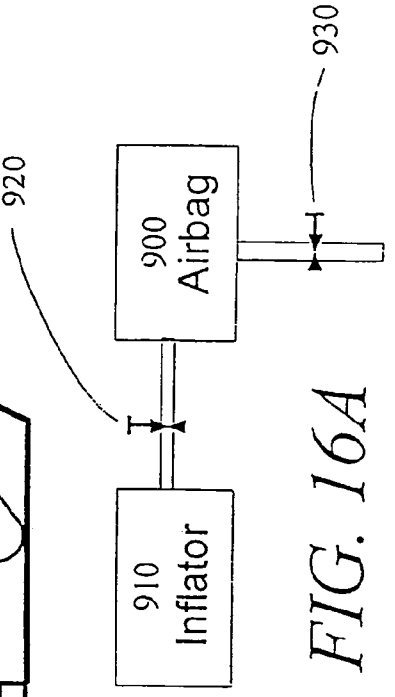


FIG. 16A

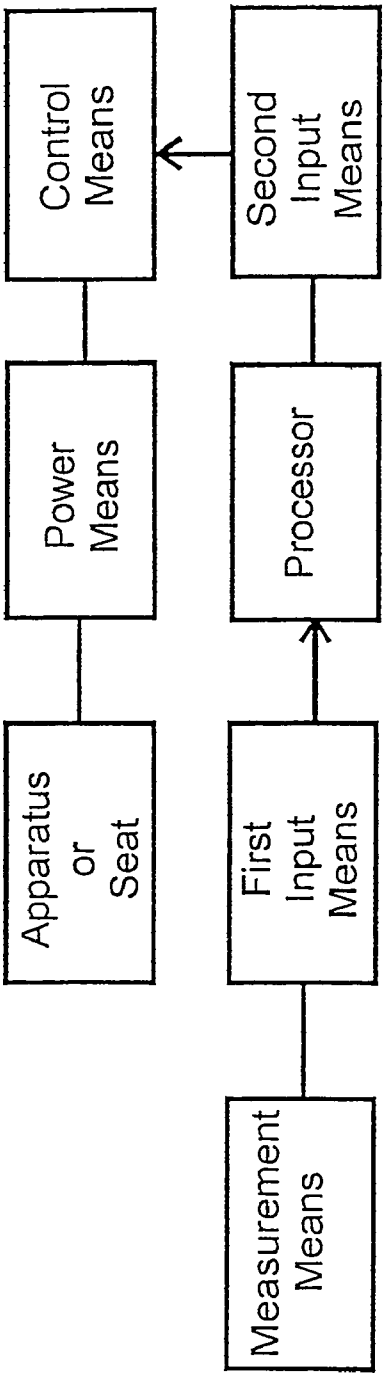


FIG. 17A

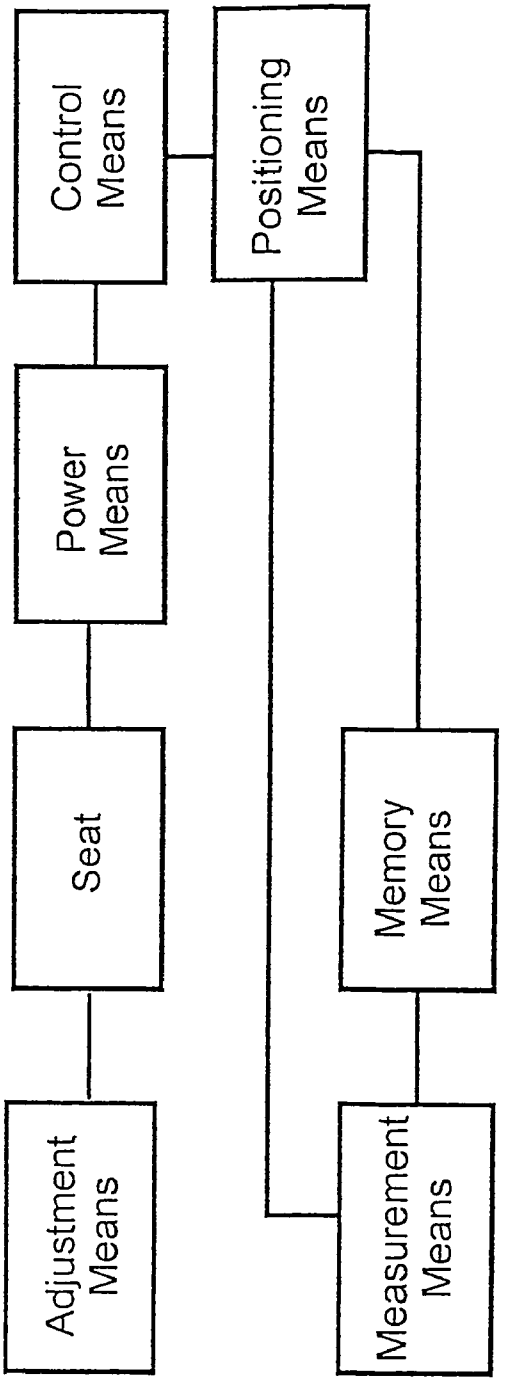


FIG. 17B

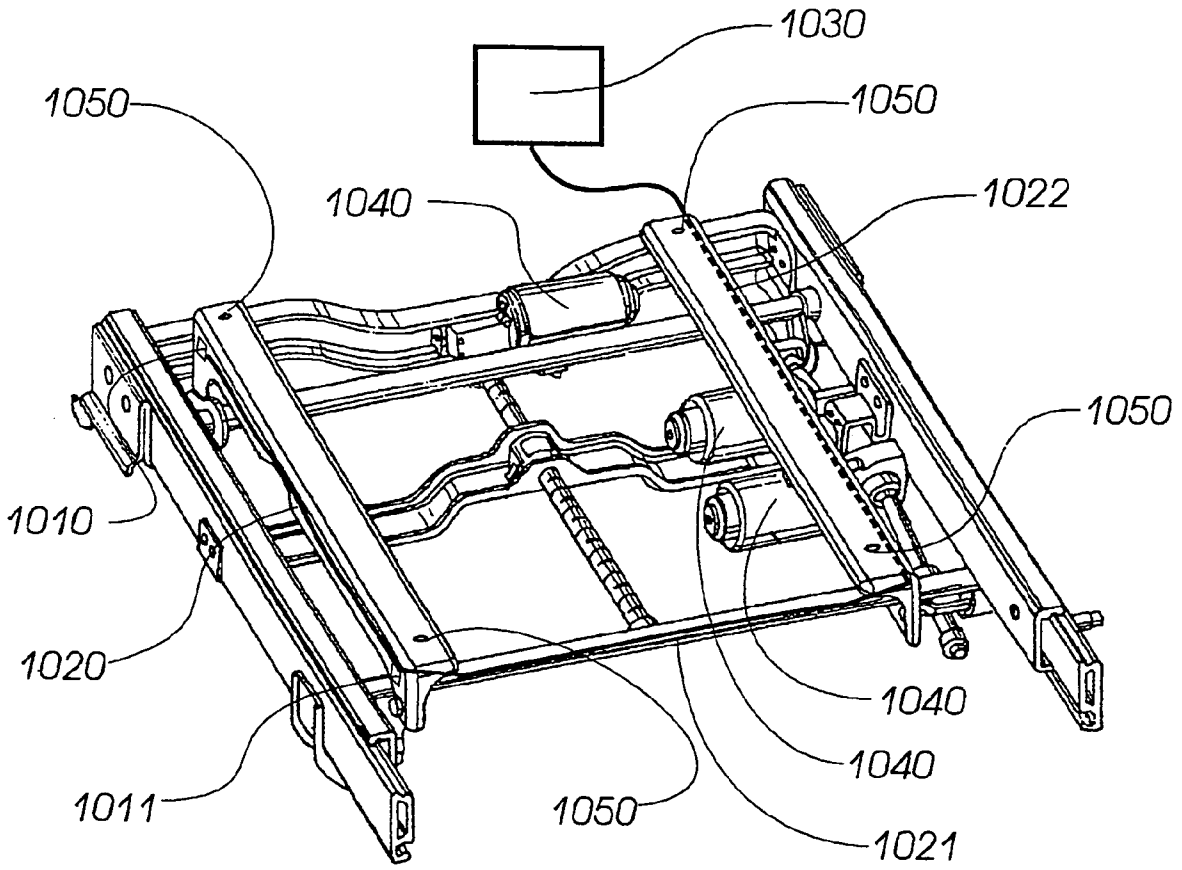

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Fig. 18

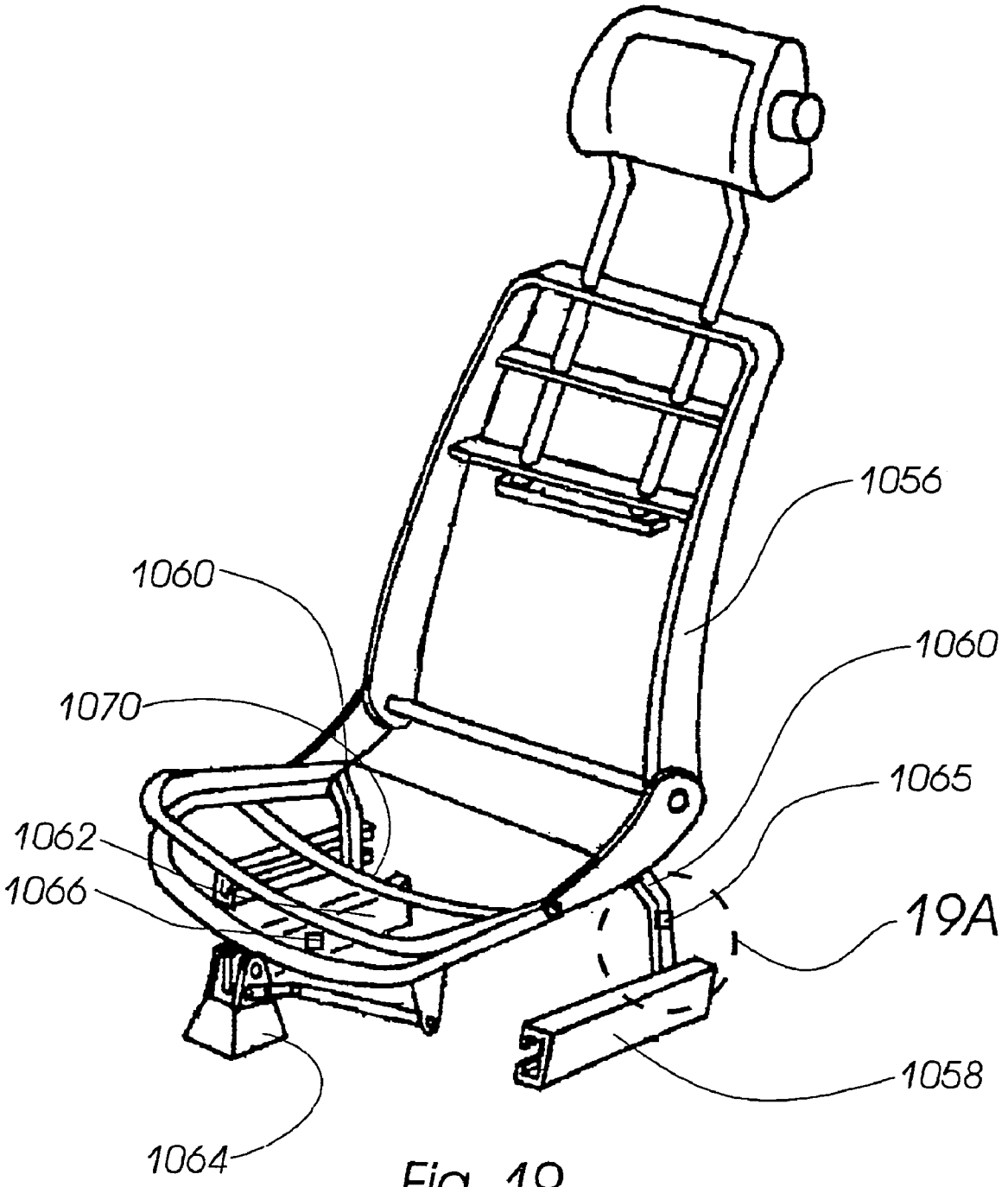


Fig. 19

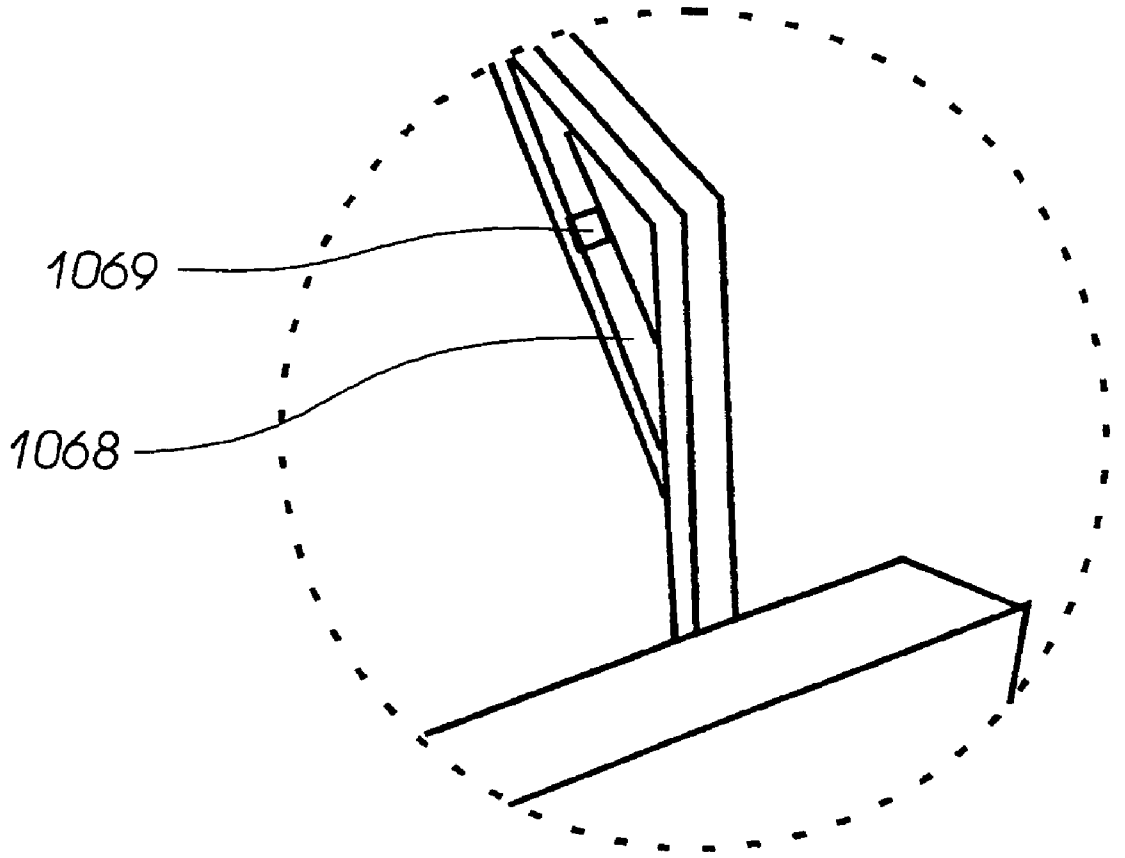


Fig. 19A

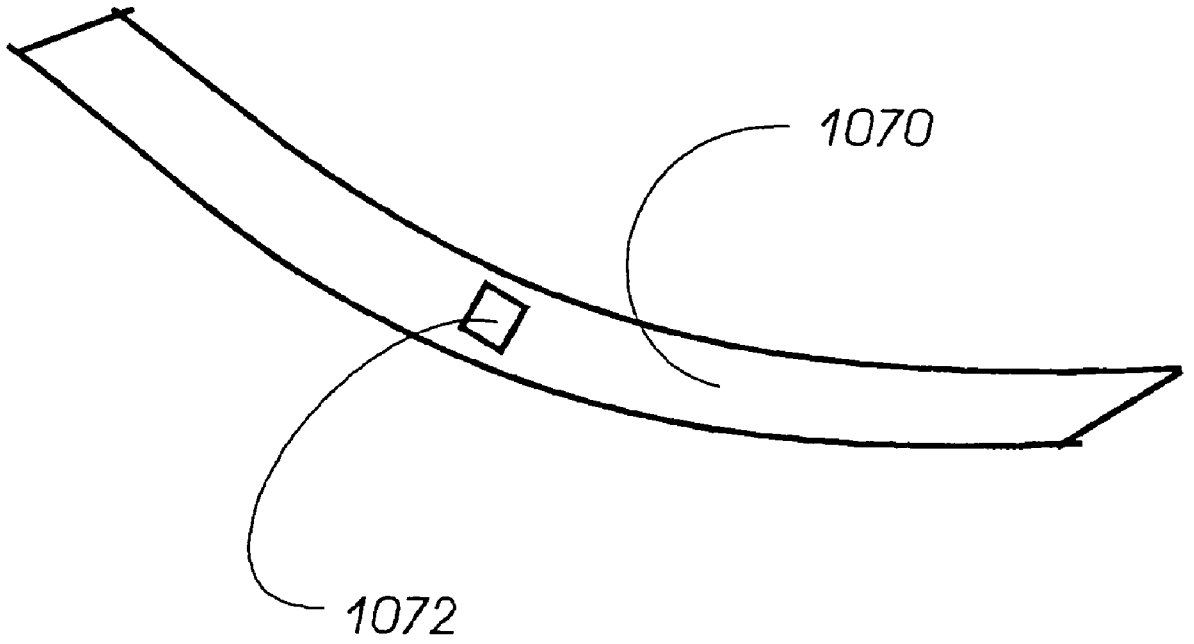


Fig. 19B

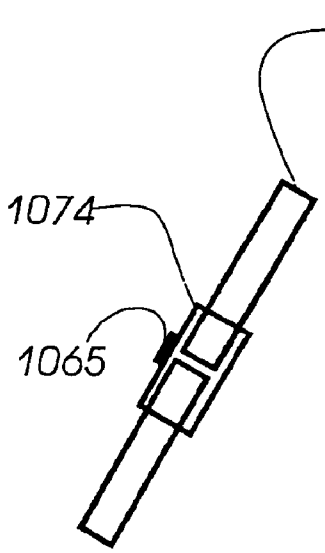


Fig. 20A

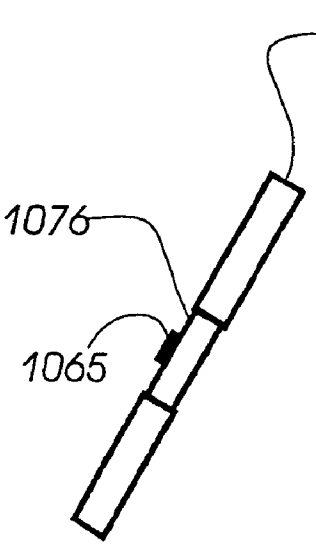


Fig. 20B

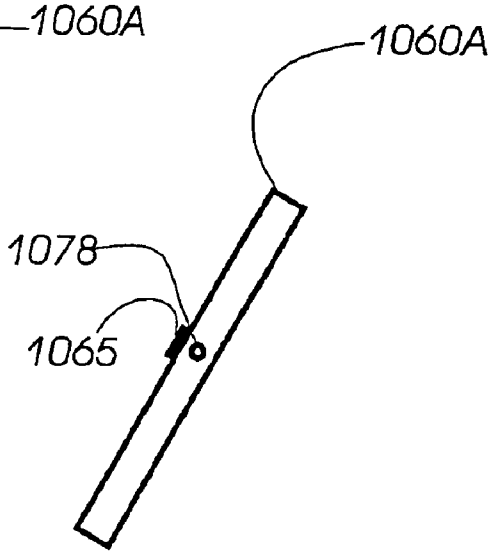


Fig. 20C

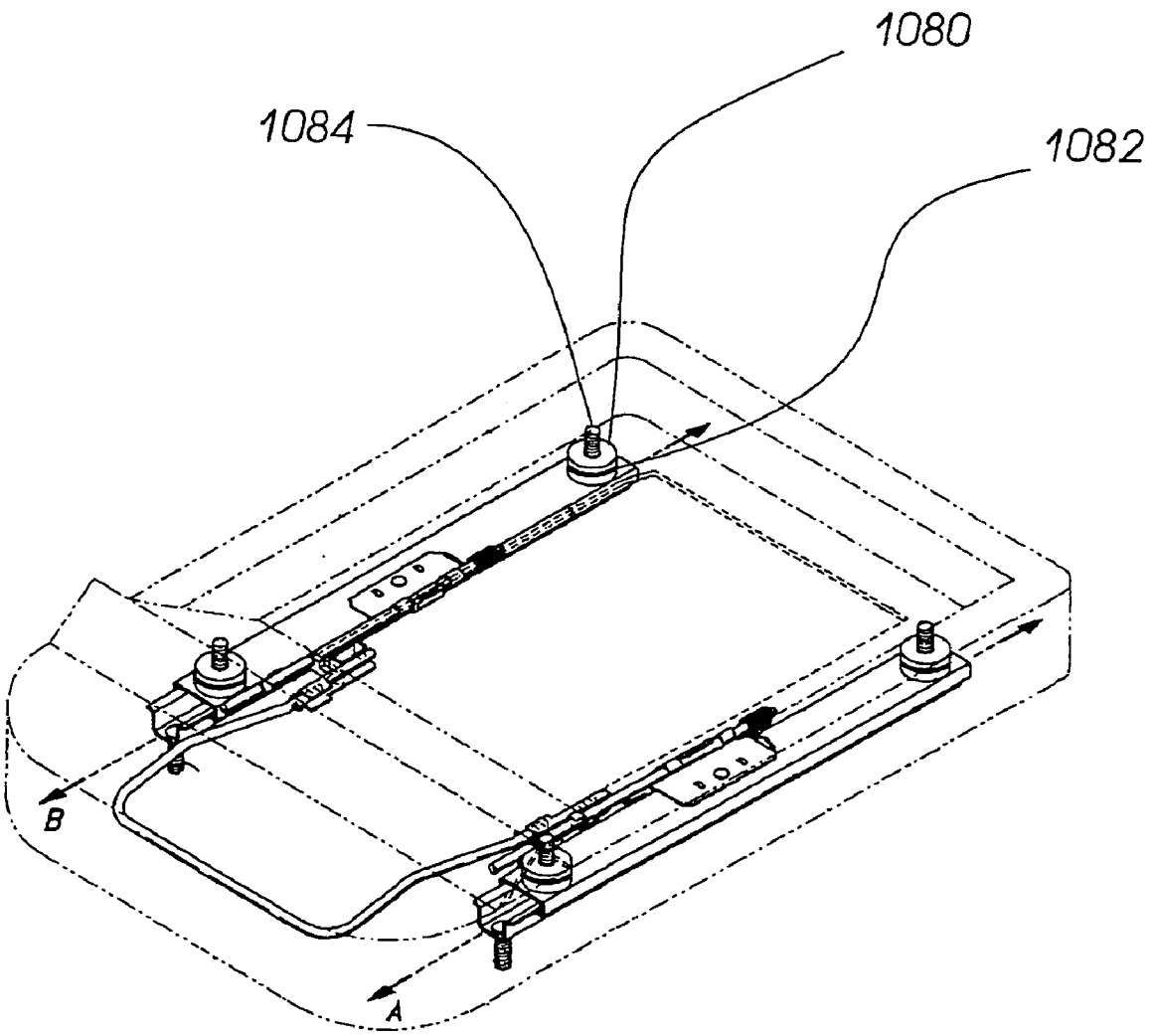


Fig. 21

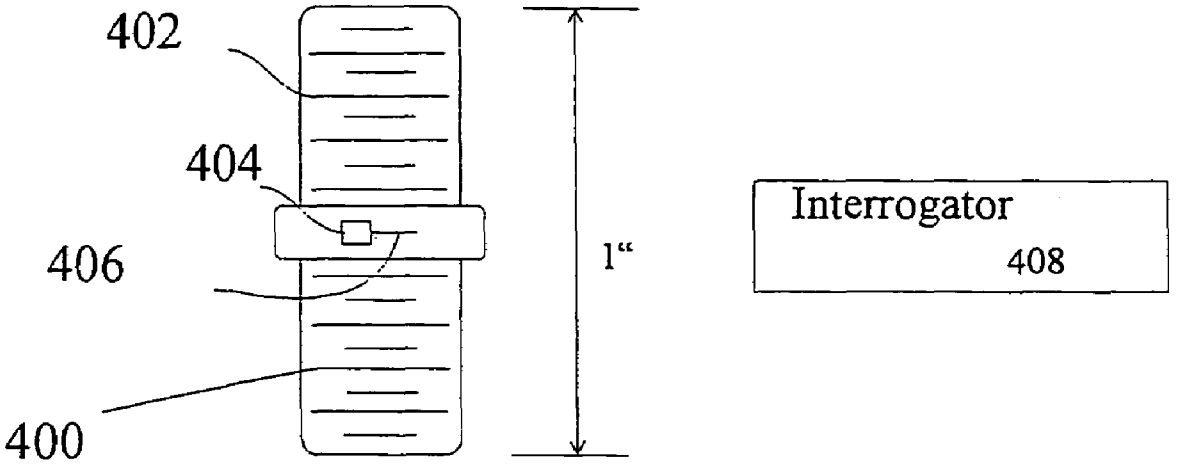


Fig. 21A

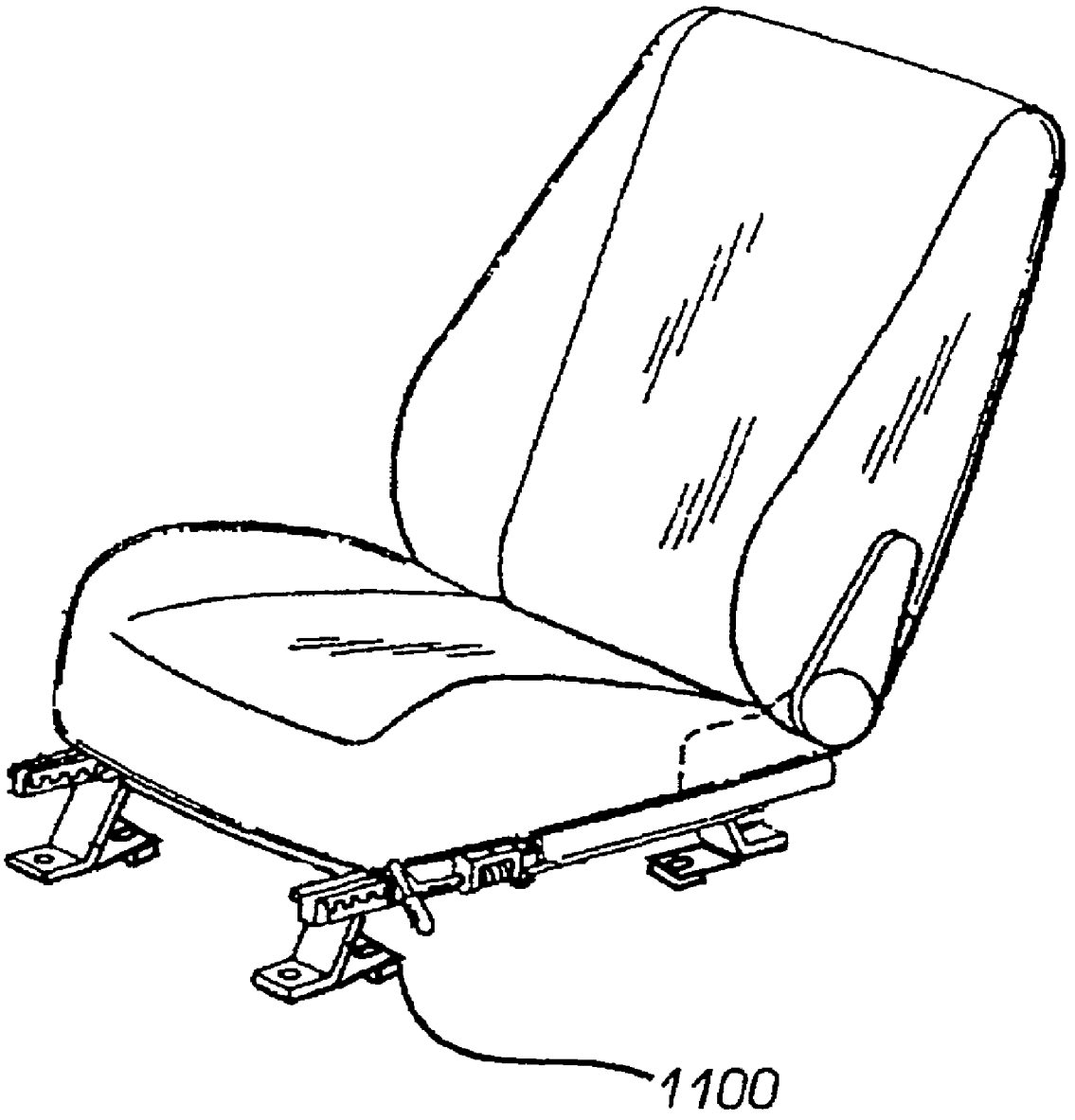


Fig. 22

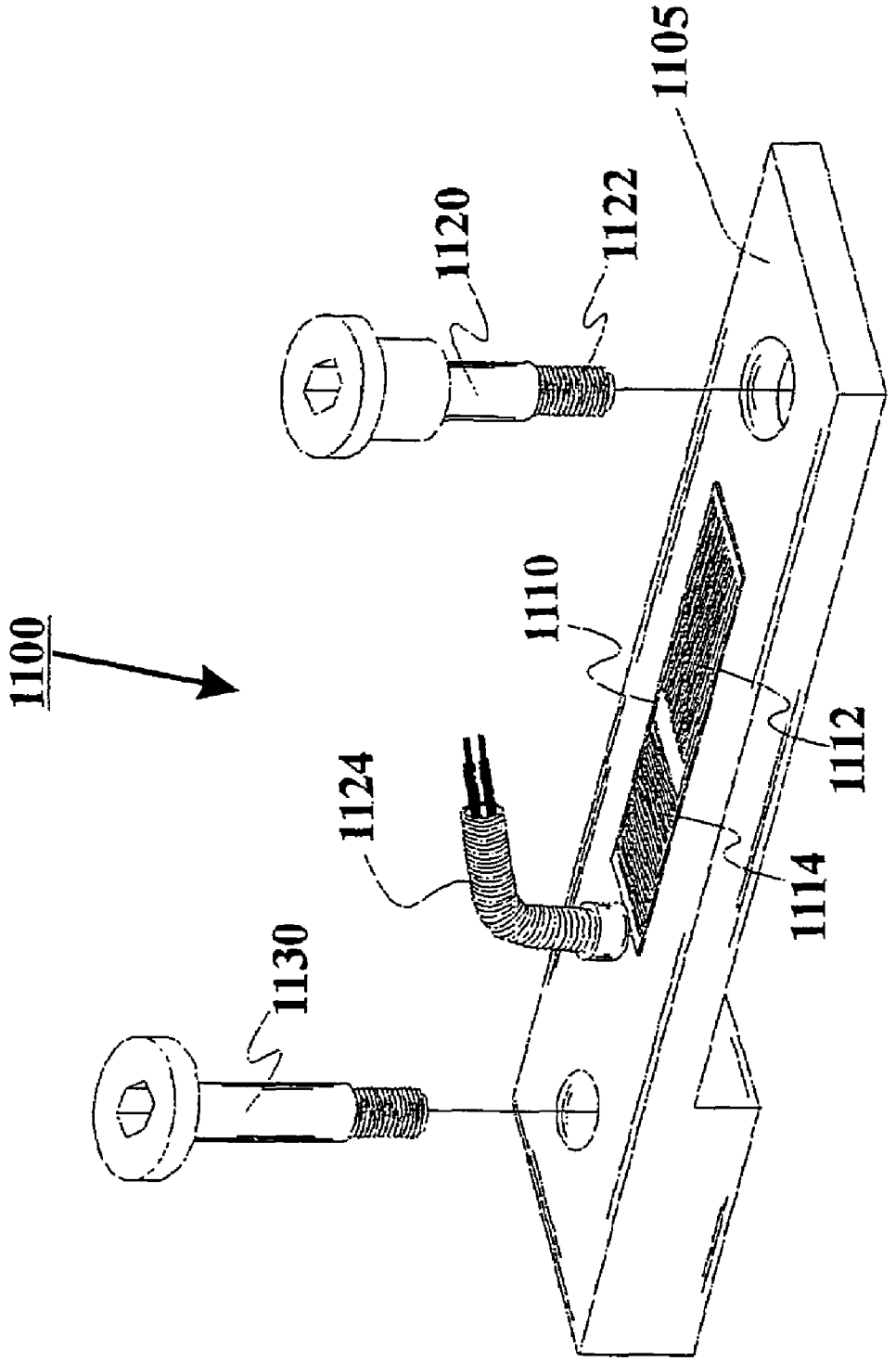


FIG. 22A

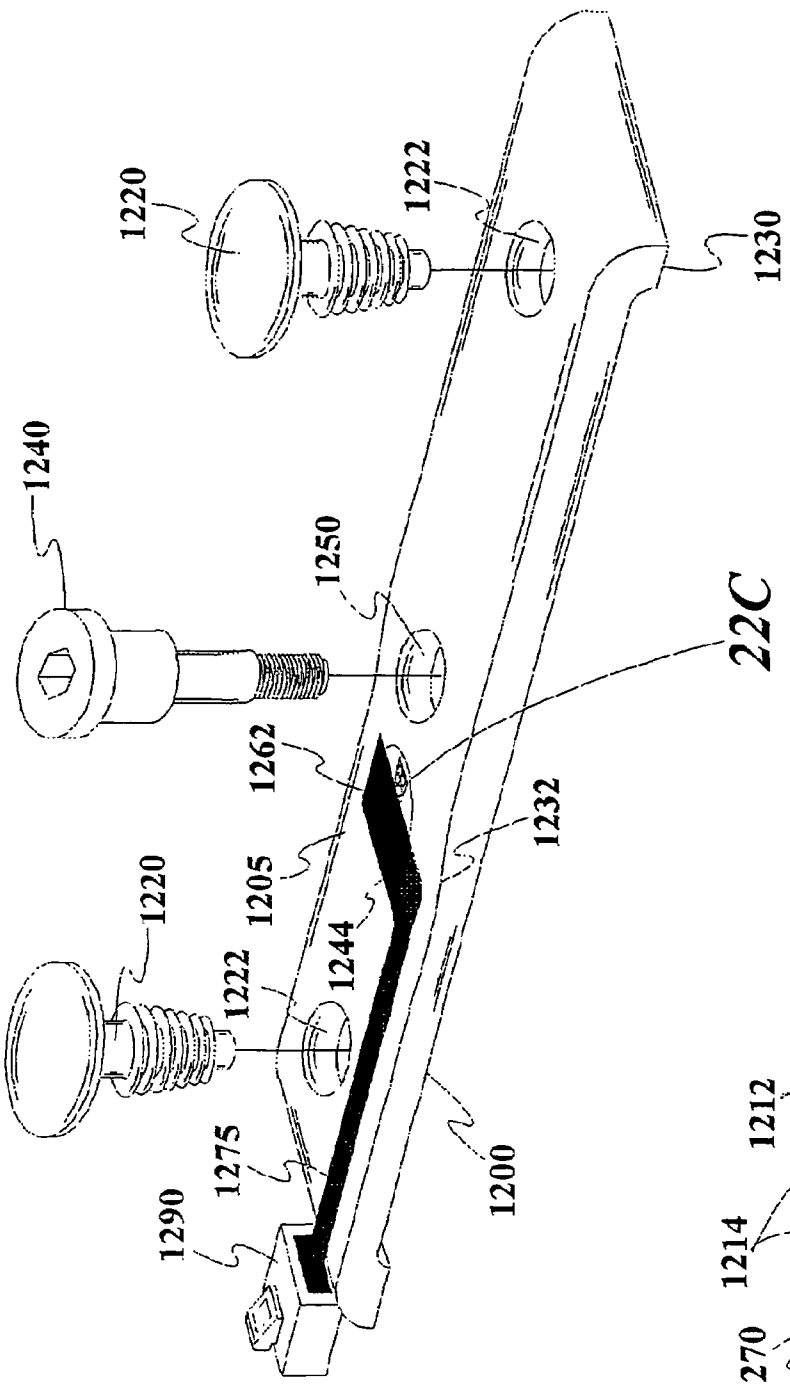


FIG. 22B

22C

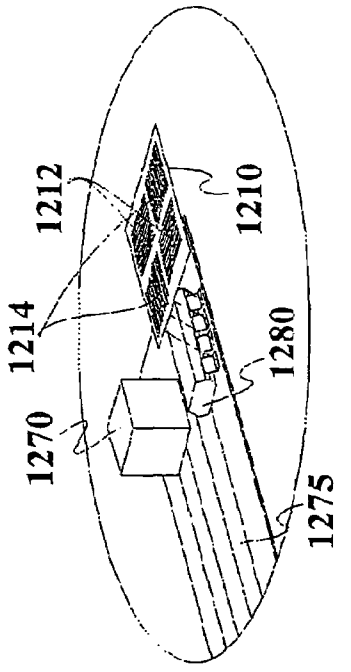


FIG. 22C

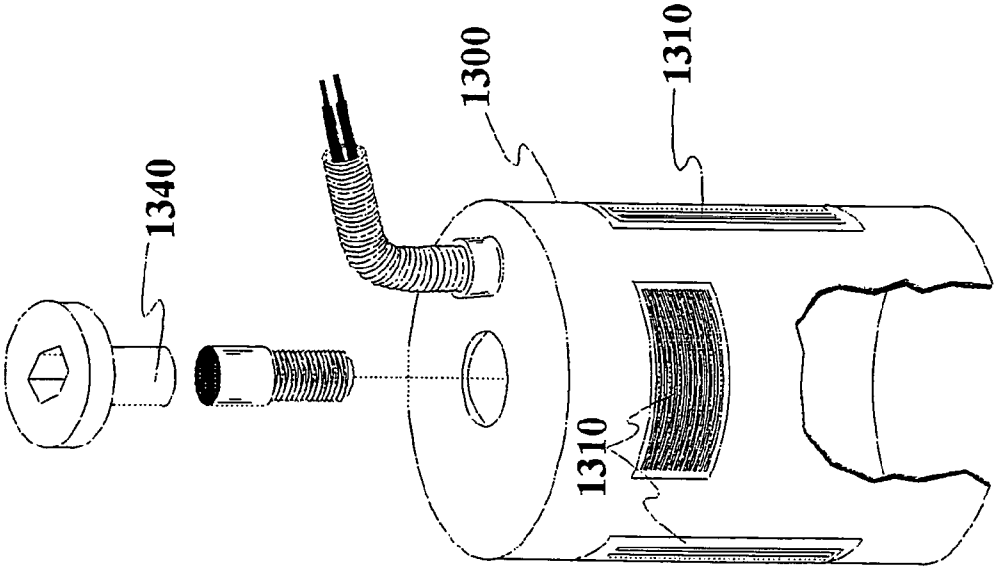


FIG. 22D

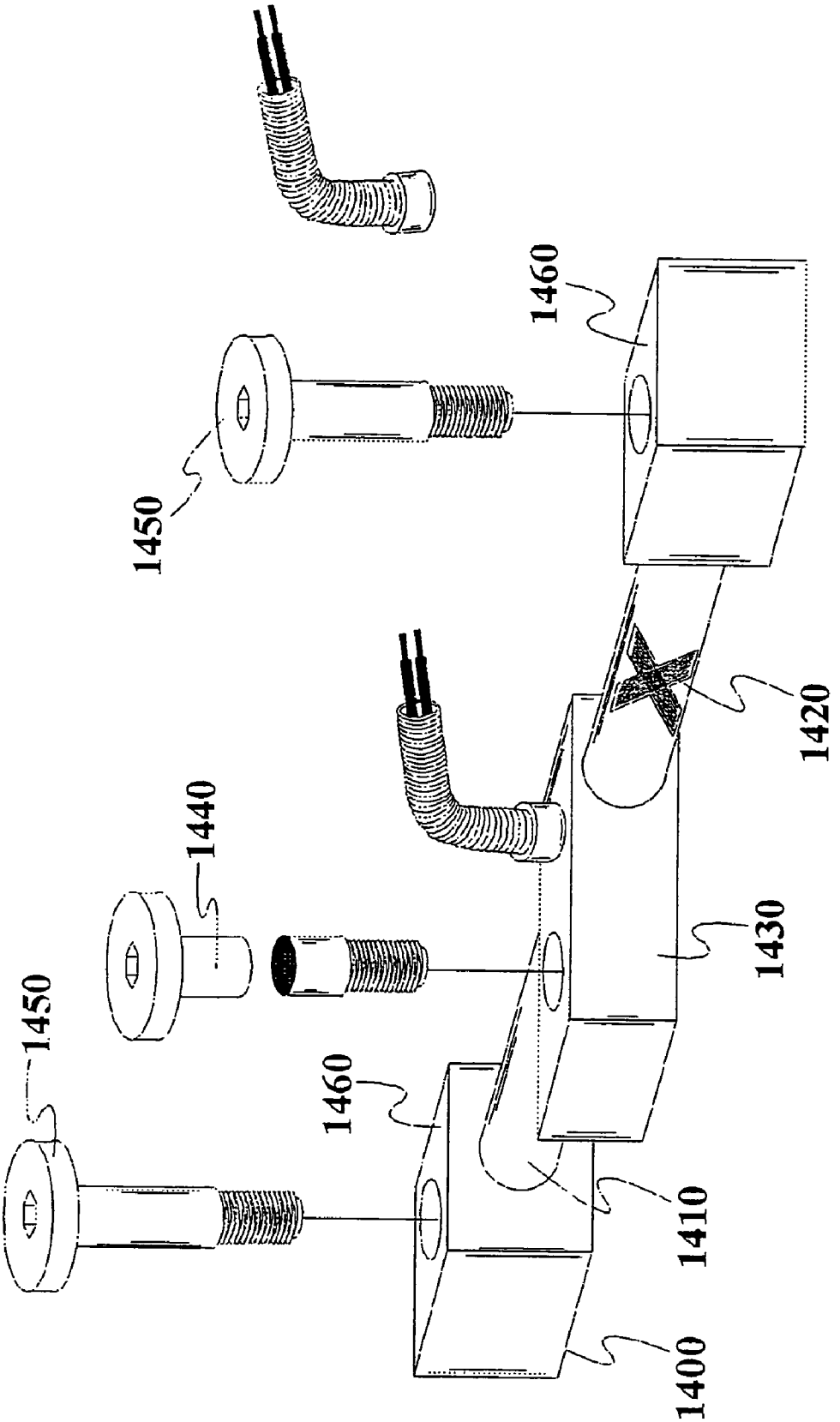
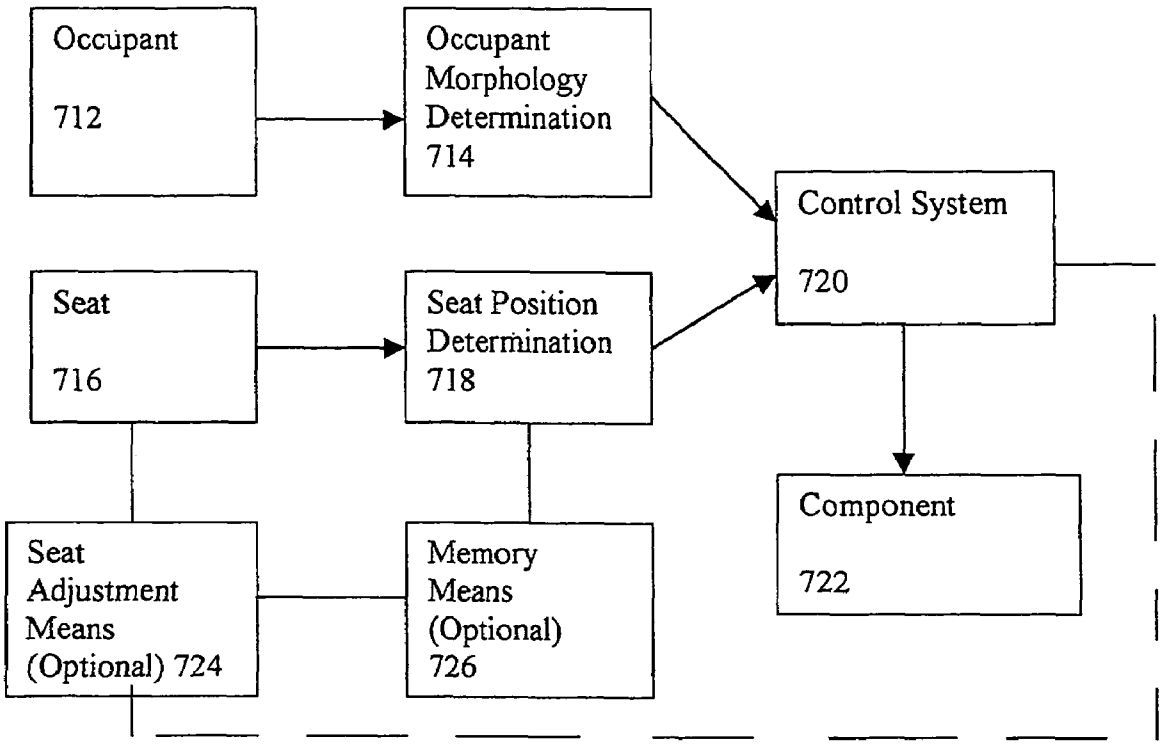


FIG. 22E

FIG. 23


Occupant
712
Occupant Morphology Determination 714
Control System
720
Seat
716
Seat Position Determination 718
Component
722
Seat Adjustment Means (Optional) 724
Memory Means (Optional) 726

WEIGHT MEASURING SYSTEMS AND METHODS FOR VEHICLES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. patent application Ser. No. 10/733,957 filed Dec. 11, 2003 now U.S. Pat. No. 7,243,945 which is:

1. a continuation-in-part of U.S. patent application Ser. No. 09/849,559 filed May 4, 2001, now U.S. Pat. No. 6,689,962, which is a continuation-in-part of U.S. patent application Ser. No. 09/193,209 filed Nov. 17, 1998, now U.S. Pat. No. 6,242,701, which is a continuation-in-part of U.S. patent application Ser. No. 09/128,490 filed Aug. 4, 1998, now U.S. Pat. No. 6,078,854, which is:

A) a continuation-in-part of U.S. patent application Ser. No. 08/474,783 filed Jun. 7, 1995, now U.S. Pat. No. 5,822,707; and

B) a continuation-in-part of U.S. patent application Ser. No. 08/970,822 filed Nov. 14, 1997, now U.S. Pat. No. 6,081,757;

2. a continuation-in-part of U.S. patent application Ser. No. 10/061,016 filed Jan. 30, 2002 now U.S. Pat. No. 6,833,516 which is a continuation-in-part of U.S. patent application Ser. No. 09/901,879 filed Jul. 9, 2001, now U.S. Pat. No. 6,555,766, which is a continuation-in-part of U.S. patent application Ser. No. 09/849,559 filed May 4, 2001, now U.S. Pat. No. 6,689,962 (the history of which is set forth above); and

3. a continuation-in-part of U.S. patent application Ser. No. 10/227,781 filed Aug. 26, 2002 now U.S. Pat. No. 6,792,342 which is:

A) a continuation-in-part of U.S. patent application Ser. No. 10/061,016 filed Jan. 30, 2002 (the history of which is set forth above); and

B) a continuation-in-part of U.S. patent application Ser. No. 09/500,346 filed Feb. 8, 2000, now U.S. Pat. No. 6,442,504, which is a continuation-in-part of U.S. patent application Ser. No. 09/128,490 filed Aug. 4, 1998, now U.S. Pat. No. 6,078,854, which is:

1) a continuation-in-part of U.S. patent application Ser. No. 08/474,783 filed Jun. 7, 1995, now U.S. Pat. No. 5,822,707; and

2) a continuation-in-part of U.S. patent application Ser. No. 08/970,822 filed Nov. 14, 1997, now U.S. Pat. No. 6,081,757. All of these applications are incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for controlling a vehicle component, system or subsystem based on occupancy of a seat. The occupancy of the seat can be reflected in a property or state of the occupant of a seat and the position of the seat.

The vehicle component, system or subsystem, hereinafter referred to simply as a component may be a system such an as airbag system, the deployment or suppression of which is controlled based on the occupancy of the seat and/or location of the seat. The component may also be an adjustable portion of a system the operation of which might be advantageously adjusted based on the occupancy of the seat and/or the location of the seat, such as a device for regulating the inflation or deflation of an airbag that is associated with an airbag system.

In addition, the component may be any adjustable component of the vehicle including, but not limited to, the bottom portion and backrest of the seat, the rear view and side mirrors, the brake, clutch and accelerator pedals, the steering wheel, the steering column, a seat armrest, a cup holder, the mounting unit for a cellular telephone or another communications or computing device and the visors.

BACKGROUND OF THE INVENTION

A thorough description of background of the invention is found in U.S. patent application Ser. No. 10/733,957, incorporated by reference herein. Also, all patents, patent applications, technical papers and other references mentioned herein are incorporated by reference in their entirety.

The use of pattern recognition, or more particularly how it is used, is important to some aspects of the instant invention. "Pattern recognition" as used herein will generally mean any system which processes a signal that is generated by an object (e.g., representative of a pattern of returned or received impulses, waves or other physical property specific to and/or characteristic of and/or representative of that object) or is modified by interacting with an object, in order to determine to which one of a set of classes that the object belongs. Such a system might determine only that the object is or is not a member of one specified class, or it might attempt to assign the object to one of a larger set of specified classes, or find that it is not a member of any of the classes in the set. The signals processed are generally a series of electrical signals coming from transducers that are sensitive to acoustic (ultrasonic) or electromagnetic radiation (e.g., visible light, infrared radiation, radar, or any other frequency), although other sources of information are frequently included.

A trainable or a trained pattern recognition system as used herein generally means a pattern recognition system which is taught to recognize various patterns constituted within signals by subjecting the system to a variety of examples. The most successful such system is the neural network. Thus, to generate the pattern recognition algorithm from returned waves, test data is first obtained which constitutes a plurality of sets of returned waves, or wave patterns, from an object (or from the space in which the object will be situated in the passenger compartment, i.e., the space above the seat) and an indication of the identity of that object, (e.g., a number of different objects are tested to obtain the unique wave patterns from each object). As such, the algorithm is generated, and stored in a computer processor, and which can later be applied to provide the identity of an object based on the wave pattern being received during use by a receiver connected to the processor and other information. For the purposes here, the identity of an object sometimes applies to not only the object itself but also to its location and/or orientation in the passenger compartment. For example, a rear facing child seat is a different object than a forward facing child seat and an out-of-position adult is a different object than a normally seated adult.

Other means of pattern recognition exist where the training is done by the researcher including Fuzzy Logic and Sensor Fusion systems.

To "identify" as used herein will generally mean to determine that the object belongs to a particular set or class. The class may be one containing, for example, all rear facing child seats, one containing all human occupants, or all human occupants not sitting in a rear facing child seat depending on the purpose of the system. In the case where

a particular person is to be recognized, the set or class will contain only a single element, i.e., the person to be recognized.

To "ascertain the identity of" as used herein with reference to an object will generally mean to determine the type or nature of the object (obtain information as to what the object is), i.e., that the object is an adult, an occupied rear facing child seat, an occupied front facing child seat, an unoccupied rear facing child seat, an unoccupied front facing child seat, a child, a dog, a bag of groceries, etc.

An "object" or "occupying item" of a seat may be a living occupant such as a human or a dog, another living organism such as a plant, or an inanimate object such as a box or bag of groceries or an empty child seat.

"Out-of-position" as used for an occupant will generally means that the occupant, either the driver or a passenger, is sufficiently close to the occupant protection apparatus (airbag) prior to deployment that he or she is likely to be more seriously injured by the deployment event itself than by the accident. It may also mean that the occupant is not positioned appropriately in order to attain the beneficial, restraining effects of the deployment of the airbag. As for the occupant being too close to the airbag, this typically occurs when the occupant's head or chest is closer than some distance such as about 5 inches from the deployment door of the airbag module. The actual distance value where airbag deployment should be suppressed depends on the design of the airbag module and is typically farther for the passenger airbag than for the driver airbag.

"Transducer" as used herein will generally mean the combination of a transmitter and a receiver. In some cases, the same device will serve both as the transmitter and receiver while in others two separate devices adjacent to each other will be used. In some cases, a transmitter is not used and in such cases transducer will mean only a receiver. Transducers include, for example, capacitive, inductive, ultrasonic, electromagnetic (antenna, CCD, CMOS arrays), weight measuring or sensing devices.

"Adaptation" as used here represents the method by which a particular occupant sensing system is designed and arranged for a particular vehicle model. It includes such things as the process by which the number, kind and location of various transducers is determined. For pattern recognition systems, it includes the process by which the pattern recognition system is taught to recognize the desired patterns. In this connection, it will usually include (1) the method of training, (2) the makeup of the databases used for training, testing and validating the particular system, or, in the case of a neural network, the particular network architecture chosen, (3) the process by which environmental influences are incorporated into the system, and (4) any process for determining the pre-processing of the data or the post processing of the results of the pattern recognition system. The above list is illustrative and not exhaustive. Basically, adaptation includes all of the steps that are undertaken to adapt transducers and other sources of information to a particular vehicle to create the system that accurately identifies and determines the location of an occupant or other object in a vehicle.

OBJECTS OF THE INVENTION

Accordingly, it is a principal object of the present invention to provide new and improved arrangements and methods for adjusting or controlling a component in a vehicle. Control of a component does not require an adjustment of the component if the operation of the component is appropriate for the situation.

It is another object of the present invention to provide new and improved methods and apparatus for adjusting a component in a vehicle based on occupancy of the vehicle. For example, an airbag system may be controlled based on the location of a seat and the occupant of the seat to be protected by the deployment of the airbag.

It is another object of the present invention to provide new and improved arrangements and methods for controlling an occupant protection device based on the morphology of an occupant to be protected by the actuation of the device and optionally, the location of a seat on which the occupant is sitting. Control of the occupant protection device can entail suppression of actuation of the device, or adjusting of the actuation parameters of the device if such adjustment is deemed necessary.

Additional objects and advantages of this and other disclosed inventions include:

1. To provide a system for passively and automatically adjusting the position of a vehicle component to a near optimum location based on the size of an occupant.

2. To provide a system for recognizing a particular occupant of a vehicle and thereafter adjusting various components of the vehicle in accordance with the preferences of the recognized occupant.

3. To provide systems for approximately locating the eyes of a vehicle driver to thereby permit the placement of the driver's eyes at a particular location in the vehicle.

4. To provide a pattern recognition system to permit more accurate location of an occupant's head and the parts thereof and to use this information to adjust a vehicle component.

5. To provide a method of determining whether a seat is occupied and, if not, leaving the seat at a neutral position.

6. To provide a system for automatically adjusting the position of various components of the vehicle to permit safer and more effective operation of the vehicle including the location of the pedals and steering wheel.

7. To determine whether an occupant is out-of-position relative to the airbag and if so, to suppress deployment of the airbag in a situation in which the airbag would otherwise be deployed.

8. To adjust the flow of gas into and/or out of the airbag based on the morphology and position of the occupant to improve the performance of the airbag in reducing occupant injury.

9. To provide a system where the morphological characteristics of an occupant are measured by sensors located within the seat.

10. To provide a system and method wherein the weight of an occupant is determined utilizing sensors located on the seat structure.

11. To provide apparatus and methods for measuring the weight of an occupying item on a vehicle seat which may be integrated into vehicular component adjustment apparatus and methods which evaluate the occupancy of the seat and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat.

12. To provide vehicular seats including a weight measuring feature and weight measuring methods for implementation in connection with vehicular seats.

13. To provide vehicular seats in which the weight applied by an occupying item to the seat is measured based on capacitance between conductive and/or metallic members underlying the seat cushion.

14. To provide adjustment apparatus and methods that evaluate the occupancy of the seat and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat and on a measurement of the occupant's weight or a measurement of a force exerted by the occupant on the seat.

15. To provide adjustment apparatus and methods that evaluate the occupancy of the seat by a combination of ultrasonic sensors and additional sensors and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat.

16. To provide adjustment apparatus and methods that reliably discriminate between a normally seated passenger and a forward facing child seat, between an abnormally seated passenger and a rear facing child seat, and whether or not the seat is empty and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based thereon.

17. To provide weight measurement systems in order to improve the accuracy of another apparatus or system which utilizes measured weight as input, e.g., a component adjustment apparatus.

18. To provide adjustment apparatus and methods that evaluate the occupancy of the seat without the problems mentioned above.

Further objects of the present invention will become apparent from the following discussion of the preferred embodiments of the invention.

SUMMARY OF THE INVENTION

Accordingly, in order to achieve one or more of the objects above, a method for determining the position of the occupant in a seat having a bottom portion on which the occupant sits and a back portion situated at an angle to the bottom portion in accordance with the invention includes arranging a bladder having at least one chamber in the bottom portion, measuring the pressure in each chamber, and determining the position of the occupant based at least on part on the measured pressure. Pressure may be measured by arranging at least one transducer in association with each chamber.

If the bladder comprises a plurality of chambers, each chamber can be arranged at a different location in the bottom portion and the weight distribution of the occupant determined based on the measured pressure in the chambers. In this case, a respective transducer may be arranged in association with each chamber.

A method for deploying an occupant protection device in an automotive vehicle to protect an occupant during a crash involving the vehicle in accordance with the invention includes determining the position of the occupant in any one of the ways set forth above, deploying the occupant protection device based at least in part on the determined position of the occupant.

A method for determining weight distribution of an occupant in a seat having a bottom portion on which the occupant sits and a back portion situated at an angle to the bottom portion includes arranging a bladder having a plurality of chambers in a seat portion of the seat, measuring the pressure in each chamber, determining the weight distribution of the occupant from the measured pressure in each chamber, and determining the center of force of the occupant on the seat based on the weight distribution. The position of the occupant can also be determined based on the weight distribution.

A vehicular occupant position arrangement for determining the position of an occupant in a seat of the vehicle having a bottom portion on which the occupant sits and a back portion situated at an angle to the bottom portion includes a sensor for determining the force applied by the occupant to the seat, the sensor comprising a bladder having at least one chamber adapted to be arranged in the bottom portion of the seat, and at least one transducer for measuring the pressure in a respective chamber, and a microprocessor coupled to the sensor and arranged to receive the determined force applied by the occupant to the seat from the sensor and determine the position of the occupant based at least on part on the determined force applied by the occupant. The bladder may include a plurality of chambers, each adapted to be arranged at a different location in the bottom portion of the seat.

A vehicle in accordance with the invention includes a seat including a bottom portion having an upper surface on which an occupant sits, a back portion arranged at an angle to the bottom portion, and a sensor for determining the force applied by the occupant to the bottom portion. The sensor includes a bladder having at least one chamber and at least one transducer for measuring the pressure in a respective chamber. A microprocessor is coupled to the sensor and arranged to receive the determined force applied by the occupant to the bottom portion from the sensor and determine the position of the occupant based at least on part on the determined force applied by the occupant. The determined position of the occupant can be used to affect or control a component in the vehicle. For example, if the vehicle includes an occupant protection device coupled to the microprocessor, the microprocessor controls the occupant protection device in consideration of the determined position of the occupant in the seat.

A method for determining the classification of the occupant in a vehicular seat includes arranging a bladder having at least one chamber in a bottom portion of the seat, measuring the pressure in each chamber, and determining the classification of the occupant based at least on part on the measured pressure. The modifications described above for the bladder and pressure measurement scheme can be applied here as well.

A method for deploying an occupant protection device in an automotive vehicle to protect an occupant during a crash involving the vehicle in accordance with the invention entails determining the classification of the occupant as set forth above and deploying the occupant protection device based in part on the determined classification of the occupant.

A vehicular occupant classification system for determining the classification of an occupant in a seat of the vehicle having a bottom portion on which the occupant sits and a back position situated at an angle to the bottom portion in accordance with the invention includes a sensor for determining the force applied by the occupant to the seat and a microprocessor coupled to the sensor. The sensor includes a bladder having at least one chamber adapted to be arranged in the bottom portion of the seat, and at least one transducer for measuring the pressure in a respective chamber. The microprocessor receives the determined force applied by the occupant to the seat from the sensor and determines the classification of the occupant based at least on part on the

determined force applied by the occupant. The modifications described above for the bladder and pressure measurement scheme can be applied here as well.

A vehicle in accordance with the invention includes a seat including a bottom portion having an upper surface on which an occupant sits, a back portion arranged at an angle to the bottom portion, and a sensor for determining the force applied by the occupant to the bottom portion. The sensor includes a bladder having at least one chamber and at least one transducer for measuring the pressure in a respective chamber. A microprocessor is coupled to the sensor and receives the determined force applied by the occupant to the bottom portion from the sensor and determines the classification of the occupant based at least on part on the determined force applied by the occupant. The determined classification of the occupant is used to affect or control a component in the vehicle. The modifications described above for the bladder and pressure measurement scheme can be applied here as well.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of embodiments of the invention and are not meant to limit the scope of the invention as encompassed by the claims.

FIG. **1** shows a seated-state detecting unit in accordance with the present invention and the connections between ultrasonic or electromagnetic sensors, a weight sensor, a reclining angle detecting sensor, a seat track position detecting sensor, a heartbeat sensor, a motion sensor, a neural network, and an airbag system installed within a vehicle compartment.

FIG. **1**A is an illustration as in FIG. **1** with the replacement of a strain gage weight sensor within a cavity within the seat cushion for the bladder weight sensor of FIG. **1**.

FIG. **2** is a perspective view of a vehicle showing the position of the ultrasonic or electromagnetic sensors relative to the driver and front passenger seats.

FIG. **3** is a circuit diagram of the seated-state detecting unit of the present invention.

FIGS. **4**(*a*), **4**(*b*) and **4**(*c*) are each a diagram showing the configuration of the reflected waves of an ultrasonic wave transmitted from each transmitter of the ultrasonic sensors toward the passenger seat, obtained within the time that the reflected wave arrives at a receiver, FIG. **4**(*a*) showing an example of the reflected waves obtained when a passenger is in a normal seated-state, FIG. **4**(*b*) showing an example of the reflected waves obtained when a passenger is in an abnormal seated-state (where the passenger is seated too close to the instrument panel), and FIG. **4**(*c*) showing a transmit pulse.

FIG. **5** is a diagram of the data processing of the reflected waves from the ultrasonic or electromagnetic sensors.

FIG. **6** is a flowchart showing the training steps of a neural network.

FIG. **7**(*a*) is an explanatory diagram of a process for normalizing the reflected wave and shows normalized reflected waves.

FIG. **7**(*b*) is a diagram similar to FIG. **7**(*a*) showing a step of extracting data based on the normalized reflected waves and a step of weighting the extracted data by employing the data of the seat track position detecting sensor, the data of the reclining angle detecting sensor, and the data of the weight sensor.

FIG. **8** is a perspective view of an automatic seat adjustment system, with the seat shown in phantom, with a movable headrest and sensors for measuring the height of the occupant from the vehicle seat showing motors for moving the seat and a control circuit connected to the sensors and motors.

FIG. **9** is a perspective view of the seat shown in FIG. **8** with the addition of a weight sensor shown mounted onto the seat.

FIG. **9**A is a view taken along line **9**A-**9**A in FIG. **9**.

FIG. **9**B is an enlarged view of the section designated **9**B in FIG. **9**A.

FIG. **9**C is a view of another embodiment of a seat with a weight sensor similar to the view shown in FIG. **9**A.

FIG. **9**D is a view of another embodiment of a seat with a weight sensor in which a SAW strain gage is placed on the bottom surface of the cushion.

FIG. **10** is a side plan view of the interior of an automobile, with portions cut away and removed, with two occupant height measuring sensors, one mounted into the headliner above the occupant's head and the other mounted onto the A-pillar and also showing a seatbelt associated with the seat wherein the seatbelt has an adjustable upper anchorage point which is automatically adjusted based on the height of the occupant.

FIG. **11** is a view of the seat of FIG. **8** showing motors for changing the tilt of seat back and the lumbar support.

FIG. **12** is a view of the seat of FIG. **8** showing a system for changing the stiffness and the damping of the seat.

FIG. **12**A is a view of the seat of FIG. **8** wherein the bladder contains a plurality of chambers.

FIG. **13** is a view as in FIG. **10** showing a driver and driver seat with an automatically adjustable steering column and pedal system which is adjusted based on the morphology of the driver.

FIG. **14** is a perspective view of the interior of the passenger compartment of an automobile, with parts cut away and removed, showing a variety of transmitters that can be used in a phased array system.

FIG. **15** is a view similar to FIG. **8** showing the occupant's eyes and the seat adjusted to place the eyes at a particular vertical position for proper viewing through the windshield and rear view mirror.

FIG. **16** is a view similar to FIG. **8** showing an inflated airbag and an arrangement for controlling both the flow of gas into and the flow of gas out of the airbag during the crash where the determination is made based on a height sensor located in the headrest and a weight sensor in the seat.

FIG. **17**A is a schematic drawing of the basic embodiment of the adjustment system in accordance with the invention.

FIG. **17**B is a schematic drawing of another basic embodiment of the adjustment system in accordance with the invention.

FIG. **18** is a perspective view of a one embodiment of an apparatus for measuring the weight of an occupying item of a seat illustrating weight sensing transducers mounted on a seat control mechanism portion which is attached directly to the seat.

FIG. **19** illustrates a seat structure with the seat cushion and back cushion removed illustrating a three-slide attachment of the seat to the vehicle and preferred mounting locations on the seat structure for strain measuring weight sensors of an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention.

FIG. **19**A illustrates an alternate view of the seat structure transducer mounting location taken in the circle A of FIG. **19** FIG. with the addition of a gusset and where the strain gage is mounted onto the gusset.

FIG. **19**B illustrates a mounting location for a weight sensing transducer on a centralized transverse support mem-

ber in an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention.

FIGS. **20**A, **20**B and **20**C illustrate three alternate methods of mounting strain transducers of an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention onto a tubular seat support structural member.

FIG. **21** illustrates an alternate weight sensing transducer utilizing pressure sensitive transducers.

FIG. **21** A illustrates a part of another alternate weight sensing system for a seat.

FIG. **22** illustrates an alternate seat structure assembly utilizing strain transducers.

FIG. **22**A is a perspective view of a cantilevered beam type load cell for use with the weight measurement system of this invention for mounting locations of FIG. **22**, for example.

FIG. **22**B is a perspective view of a simply supported beam type load cell for use with the weight measurement system of this invention as an alternate to the cantilevered load cell of FIG. **22**A.

FIG. **22**C is an enlarged view of the portion designated **22**C in FIG. **22**B.

FIG. **22**D is a perspective view of a tubular load cell for use with the weight measurement system of this invention as an alternate to the cantilevered load cell of FIG. **22**A.

FIG. **22**E is a perspective view of a torsional beam load cell for use with the weight measurement apparatus in accordance with the invention as an alternate to the cantilevered load cell of FIG. **22**A.

FIG. **23** is a flow chart of an arrangement for controlling a component in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. **12**, the airbag or bladder **515** which interacts with the occupant is shown with a single chamber. Naturally, bladder **515** can be composed of multiple chambers **518***a*, **518***b*, **518***c*, **518***d* as shown in FIG. **12**A. The use of multiple chambers permits the weight distribution of the occupant to be determined if a separate pressure transducer is used in each cell of the bladder. Such a scheme gives the opportunity of determining to some extent the position of the occupant on the seat or at least the position of the center of gravity of the occupant. Naturally, more than four cells could be used.

Weight measuring means such as the sensor **6** and **7** are associated with the seat, e.g., mounted into or below the seat portion **2** or on the seat structure, for measuring the weight applied onto the seat. The weight may be zero if no occupying item is present and the sensors are optionally calibrated to only measure incremental weight. Sensor **6** and **7** may represent a plurality of different sensors which measure the weight applied onto the seat at different portions thereof or for redundancy purposes, e.g., such as by means of an airbag or fluid-filled bladder **5** in the seat portion **2**. Airbag or bladder **5** may contain a single or a plurality of chambers, each of which is associated with a sensor (transducer) **6** for measuring the pressure in the chamber. Such sensors may be in the form of strain, force or pressure sensors which measure the force or pressure on the seat, a part of the seat or seat back, displacement measuring sensors which measure the displacement of the seat surface or the entire seat such as through the use of strain gages mounted on the seat structural members, such as **7**, or other appropriate locations, or systems which convert displacement into a pressure wherein one or more pressure sensors can be used as a measure of weight and/or weight distribution. Sensors **7**,**76** may be of the types disclosed in US06242701.

As shown in FIG. **2**, there are provided four sets of wave-receiving sensor systems **11**-**14** mounted within the passenger compartment. Each set of sensor systems **11**-**14** comprises a transmitter and a receiver (or just a receiver in some cases), which may be integrated into a single unit or individual components separated from one another. In this embodiment, the sensor system **11** is mounted on the upper portion of the front pillar, A-Pillar, of the vehicle. The sensor system **12** is mounted on the upper portion of the intermediate pillar, B-Pillar. The sensor system **13** is mounted on the roof ceiling portion or the headliner (FIG. **2**). The sensor system **14** is mounted near the middle of an instrument panel **17** in front of the driver's seat **16** (FIG. **2**). The sensor systems are preferably ultrasonic or electromagnetic. Although sensor systems **11**-**14** are described as being ultrasonic or electromagnetic sensors, the invention is equally applicable for other types of sensors (other than ultrasonic or electromagnetic) which will detect the presence of an occupant from a distance including capacitive or electromagnetic sensors. Also, if the sensor systems **11**-**14** are passive infrared sensors, for example, then they may only comprise a wave-receiver.

The ultrasonic or electromagnetic sensor systems **11**-**14** are controlled or driven, one at a time or simultaneously, by an appropriate driver circuit such as ultrasonic or electromagnetic sensor driver circuit **18** shown in FIG. **3**. The transmitters of the ultrasonic or electromagnetic sensor systems **11**-**14** transmit respective ultrasonic or electromagnetic waves toward the seat **1** and transmit pulses (see FIG. **4**(*c*)) in sequence at times t**1**, t**2**, t**3** and t**4** (t**4**>t**3**>t**2**>t**1**) or simultaneously (t**1**=t**2**=t**3**=t**4**). The reflected waves of the ultrasonic are received by the receivers ChA-ChD of the ultrasonic or electromagnetic sensors **11**-**14**. The receiver ChA is associated with the ultrasonic or electromagnetic sensor system **13**, the receiver ChB is associated with the ultrasonic or electromagnetic sensor system **14**, the receiver ChD is associated with the ultrasonic or electromagnetic sensor system **11**, and the receiver ChD is associated with the ultrasonic or electromagnetic sensor system **12**.

The following discussion will apply to the case where ultrasonic sensors are used although a similar discussion can be presented relative to the use of electromagnetic sensors such as active infrared sensors, taking into account the differences in the technologies. Also, the following discussion will relate to an embodiment wherein the seat **1** is the front passenger seat. FIGS. **4**(*a*) and **4**(*b*) show examples of the reflected ultrasonic waves USRW that are received by receivers ChA-ChD. FIG. **4**(*a*) shows an example of the reflected wave USRW that is obtained when an adult sits in a normally seated space on the passenger seat **1**, while FIG. **4**(*b*) shows an example of the reflected wave USRW that are obtained when an adult sits in a slouching state (one of the abnormal seated-states) in the passenger seat **1**.

In the case of a normally seated passenger, as shown in FIG. **2**, the location of the ultrasonic sensor system **12** is closest to the passenger A. Therefore, the reflected wave pulse P**1** is received earliest after transmission by the receiver ChD as shown in FIG. **4**(*a*), and the width of the reflected wave pulse P**1** is larger. Next, the distance from the ultrasonic sensor **13** is closer to the passenger A, so a reflected wave pulse P**2** is received earlier by the receiver ChA compared with the remaining reflected wave pulses P**3** and P**4**. Since the reflected wave pauses P**3** and P**4** take more time than the reflected wave pulses P**1** and P**2** to arrive at the receivers ChC and ChB, the reflected wave pulses P**3** and P**4**

are received as the timings shown in FIG. **4**(*a*). More specifically, since it is believed that the distance from the ultrasonic sensor system **11** to the passenger A is slightly shorter than the distance from the ultrasonic sensor system **14** to the passenger A, the reflected wave pulse P**3** is received slightly earlier by the receiver ChC than the reflected wave pulse P**4** is received by the receiver ChB.

In the case where the passenger A is sitting in a slouching state in the passenger seat **1**, the distance between the ultrasonic sensor system **11** and the passenger A is shortest. Therefore, the time from transmission at time t**3** to reception is shortest, and the reflected wave pulse P**3** is received by the receiver ChC, as shown in FIG. **4**(*b*). Next, the distances between the ultrasonic sensor system **14** and the passenger A becomes shorter, so the reflected wave pulse P**4** is received earlier by the receiver ChB than the remaining reflected wave pulses P**2** and P**1**. When the distance from the ultrasonic sensor system **13** to the passenger A is compared with that from the ultrasonic sensor system **12** to the passenger A, the distance from the ultrasonic sensor system **13** to the passenger A becomes shorter, so the reflected wave pulse P**2** is received by the receiver ChA first and the reflected wave pulse P**1** is thus received last by the receiver ChD.

The configurations of the reflected wave pulses P**1**-P**4**, the times that the reflected wave pulses P**1**-P**4** are received, the sizes of the reflected wave pulses P**1**-P**4** are varied depending upon the configuration and position of an object such as a passenger situated on the front passenger seat **1**. FIGS. **4**(*a*) and (*b*) merely show examples for the purpose of description and therefore it is a matter of course that the present invention is not limited to these examples.

The outputs of the receivers ChA-ChD, as shown in FIG. **3**, are input to a band pass filter **20** through a multiplex circuit **19** which is switched in synchronization with a timing signal from the ultrasonic sensor drive circuit **18**. The band pass filter **20** removes a low frequency wave component from the output signal based on each of the reflected wave USRW and also removes some of the noise. The output signal based on each of the reflected wave USRW is passed through the band pass filter **20**, then is amplified by an amplifier **21**. The amplifier **21** also removes the high frequency carrier wave component in each of the reflected USRW and generates an envelope wave signal. This envelope wave signal is input to an analog/digital converter (ADC) **22** and digitized as measured data. The measured data is input to a processing circuit **23**, which is controlled by the timing signal which is in turn output from the ultrasonic sensor drive circuit **18**.

The processing circuit **23** collects measured data at intervals of 7 ms (or at another time interval with the time interval also being referred to as a time window or time period), and 47 data points are generated for each of the ultrasonic sensor systems **11**-**14**. For each of these reflected waves USRW, the initial reflected wave portion T**1** and the last reflected wave portion T**2** are cut off or removed in each time window. The reason for this will be described when the training procedure of a neural network is described later, and the description is omitted for now. With this, 32 data points, 31 data points, 37 data points, and 38 data points will be sampled by the ultrasonic sensor systems **12**, **13** and **14**, respectively. The reason why the number of data points differs for each of the ultrasonic sensor systems **11**-**14** is that the distance from the passenger seat **1** to the ultrasonic sensor systems **11**-**14** differ from one another.

Each of the measured data is input to a normalization circuit **24** and normalized. The normalized measured data is input to the neural network **25** as wave data.

The output of the weight sensor(s) **6** and **7** is amplified by an amplifier **26** coupled to the weight sensor(s) **6** and **7** and the amplified output is input to the analog/digital converter **27**.

The reclining angle detecting sensor **9** and the seat track position-detecting sensor **10**, which each may comprise a variable resistor, are connected to constant-current circuits, respectively. A constant-current is supplied from the constant-current circuit to the reclining angle detecting sensor **9**, and the reclining angle detecting sensor **9** converts a change in the resistance value on the tilt of the back portion **3** to a specific voltage. This output voltage is input to an analog/digital converter **28** as angle data, i.e., representative of the angle between the back portion **3** and the seat portion **2**. Similarly, a constant current is supplied from the constant-current circuit to the seat track position-detecting sensor **10** and the seat track position detecting sensor **10** converts a change in the resistance value based on the track position of the seat portion **2** to a specific voltage. This output voltage is input to an analog/digital converter **29** as seat track data. Thus, the outputs of the reclining angle-detecting sensor **9** and the seat track position-detecting sensor **10** are input to the analog/digital converters **28** and **29**, respectively. Each digital data value from the ADCs **28**,**29** is input to the neural network **25**. Although the digitized data of the weight sensor(s) **6** and **7** is input to the neural network **25**, the output of the amplifier **26** is also input to a comparison circuit. The comparison circuit, which is incorporated in the gate circuit algorithm, determines whether or not the weight of an object on the passenger seat **1** is more than a predetermined weight, such as 60 lbs., for example. When the weight is more than 60 lbs., the comparison circuit outputs a logic 1 to the gate circuit to be described later. When the weight of the object is less than 60 lbs., a logic 0 is output to the gate circuit.

A heartbeat sensor **31** is arranged to detect a heart beat, and the magnitude thereof, of a human occupant of the seat, if such a human occupant is present. The output of the heart beat sensor **31** is input to the neural network **25**. The heartbeat sensor **31** may be of the type as disclosed in McEwan (U.S. Pat. Nos. 5,573,012 and 5,766,208 which are incorporated herein in their entirety by reference). The heartbeat sensor **31** can be positioned at any convenient position relative the seat **1** where occupancy is being monitored. A preferred location is within the vehicle seatback.

A capacitive sensor **32** is arranged to detect the presence of an occupying item on the seat **1** and the output thereof is input to the neural network **25**. Capacitive sensors appropriate for this function are disclosed in Kithil (U.S. Pat. Nos. 5,602,734, 5,802,479 and 5,844,486 which are incorporated herein by reference) and Jinno et al. (U.S. Pat. No. 5,948,031 which is incorporated herein by reference). Capacitive sensors can in general be mounted at locations **11**-**14** in FIG. **2** or as shown in FIG. **1** or in the vehicle seat and seat back, although by their nature they can occupy considerably more space than shown in the drawings.

A motion sensor **33** is arranged to detect motion of an occupying item on the seat **1** and the output thereof is input to the neural network **25**. Motion sensors can utilize a micro-power impulse radar (MIR) system as disclosed, for example, in McEwan (U.S. Pat. No. 5,361,070, which is incorporated herein by reference), as well as many other patents by the same inventor. Motion sensing is accomplished by monitoring a particular range from the sensor as disclosed in that patent. MIR is one form of radar which has

applicability to occupant sensing and can be mounted at locations such as **11-14** in FIG. **2**. It has an advantage over ultrasonic sensors in that data can be acquired at a higher speed and thus the motion of an occupant can be more easily tracked. The ability to obtain returns over the entire occupancy range is somewhat more difficult than with ultrasound resulting in a more expensive system overall. MIR has additional advantages in lack of sensitivity to temperature variation and has a comparable resolution to about 40 kHz ultrasound. Resolution comparable to higher frequency is feasible but has not been demonstrated. Additionally, multiple MIR sensors can be used when high speed tracking of the motion of an occupant during a crash is required since they can be individually pulsed without interfering with each through time division multiplexing.

The neural network **25** recognizes the seated-state of a passenger A by training as described in several books on Neural Networks referenced in the above referenced patents and patent applications. Then, after training the seated-state of the passenger A and developing the neural network weights, the system is tested. The training procedure and the test procedure of the neural network **25** will hereafter be described with a flowchart shown in FIG. **6**.

As diagrammed in FIG. **6**, the first step is to mount the four sets of ultrasonic sensor systems **11-14**, the weight sensors **6** and **7**, the reclining angle detecting sensor **9**, and the seat track position detecting sensor **10** into a vehicle (step S**1**). Next, in order to provide data for the neural network **25** to learn the patterns of seated states, data is recorded for patterns of all possible seated states and a list is maintained recording the seated states for which data was acquired. The data from the sensors/transducers **6**, **7**, **9-14** and **31-33**, for a particular occupancy of the passenger seat is called a vector (step S**2**). It should be pointed out that the use of the reclining angle detecting sensor **9**, seat track position detecting sensor **10**, heart beat sensor **31**, capacitive sensor **32** and motion sensor **33** are not essential to the detecting apparatus and method in accordance with the invention. However, each of these sensors, in combination with any one or more of the other sensors enhances the evaluation of the seated-state of the seat.

For the vectors of data, adults and children each with different postures, states of windows etc. within the passenger compartment, and occupied and unoccupied child seats were selected. The selected adults include people with a variety of different physiques such as fat, lean, small, large, tall, short, and glasses wearing persons. The selected children ranged from an infant to a large child (for example, about 14 year old). In addition, the selected postures include, for example, a sitting state with legs crossed on a seat, a sitting state with legs on an instrument panel, a sitting state while reading a newspaper, a book, or a map, a sitting state while holding a cup of coffee, a cellular telephone or a dictation machine, and a slouching state with and without raised knees. Furthermore, the selected compartment states include variations in the seat track position, the window-opening amount, headrest position, and varying positions of a sun-visor. Moreover, a multitude of different models of child seats are used in the forward facing position and, where appropriate, in a rear facing position. The range of weights and the corresponding normalized values are as follows:

Class	Weight Range	Normalized Value
Empty Seat	0 to 2.2 lbs.	0 to 0.01
Rear Facing Child Seat	2.2 to 60 lbs.	0.01 to 0.27
Forward Facing Child Seat	2.2 to 60 lbs.	0.01 to 0.27
Normal Position Adult	60 lbs and greater	0.27 to 1

Obviously, other weight ranges may also be used in accordance with the invention and each weight range may be tailored to specific conditions, such as different vehicles. The output of the weight sensors may not correspond directly to be weight ranges in the above table. If for example strain measuring sensors are placed on each of the vehicle seat supports, such sensors will also respond to the weight of the seat itself. That weight must therefore the remove so that only the additional weight of an occupying item is measured. Similarly it may be desirable to place strain-sensing devices on only some of the vehicle seat support structures. In such cases the weight of the occupying item can be in inferred from the output of the strain sensing sensors. This will be described in greater detail below.

Various vehicle setups were prepared by a combination of these variations and, for in this embodiment, almost 500,000 or more vectors should be prepared for the patterns to be used as data for the neural network training.

Next, based on the training data from the reflected waves of the ultrasonic sensor systems **11-14** and the other sensors **6**, **7**, **31-33**, the vector data is collected (step S**3**). Next, the reflected waves P**1**-P**4** are modified by removing the initial reflected waves from each time window with a short reflection time from an object (range gating) (period T**1** in FIG. **5**) and the last portion of the reflected waves from each time window with a long reflection time from an object (period P**2** in FIG. **5**) (step S**4**). It is believed that the reflected waves with a short reflection time from an object is due to crosstalk, that is, waves from the transmitters which leaks into each of their associated receivers ChA-ChD. It is also believed that the reflected waves with a long reflection time are reflected waves from an object far away from the passenger seat or from multipath reflections. If these two reflected wave portions are used as data, they will add noise to the training process. Therefore, these reflected wave portions are eliminated from the data.

Recent advances in transducer design have now permitted the use of a single transducer acting as both a sender (transmitter) and receiver. These same advances have substantially reduced the ringing of the transducer after the excitation pulse has been caused to die out to where targets as close as about 2 inches from the transducer can be sensed. Thus, the magnitude of the T**1** time period has been substantially reduced.

As shown in FIG. **7**(*a*), the measured data is normalized by making the peaks of the reflected wave pulses P**1**-P**4** equal (step S**5**). This eliminates the effects of different reflectivities of different objects and people depending on the characteristics of their surfaces such as their clothing Data from the weight sensor, seat track position sensor and seat reclining angle sensor are also frequently normalized based typically on fixed normalization parameters.

The data from the transducers are now also preferably fed through a logarithmic compression circuit that substantially reduces the magnitude of reflected signals from high reflectivity targets compared to those of low reflectivity. Additionally, a time gain circuit is used to compensate for the

difference in sonic strength received by the transducer based on the distance of the reflecting object from the transducer.

Therefore, the normalized data from the ultrasonic transducers the seat track position detecting sensor **10**, the reclining angle detecting sensor **9**, from the weight sensor(s) **6** and **7**, from the heart beat sensor **31**, the capacitive sensor **32** and the motion sensor **33** are input to the neural network **25**, and the neural network **25** is then trained on this data. More specifically, the neural network **25** adds up the normalized data from the ultrasonic transducers, from the seat track position detecting sensor **10**, from the reclining angle detecting sensor **9**, from the weight sensor(s) **6** and **7**, from the heart beat sensor **31**, from the capacitive sensor **32** and from the motion sensor **33** with each data point multiplied by a associated weight according to the conventional neural network process to determine correlation function (step S**6**).

In this embodiment, 144 data points are appropriately interconnected at 25 connecting points of layer **1**, and each data point is mutually correlated through the neural network training and weight determination process. The 144 data points consist of 138 measured data points from the ultrasonic transducers, the data (139th) from the seat track position detecting sensor **10**, the data (140th) from the reclining angle detecting sensor **9**, the data (141st) from the weight sensor(s) **6**, the data (142^{nd}) from the heart beat sensor **31**, the data (143^{rd}) from the capacitive sensor and the data (144^{th}) from the motion sensor. Each of the connecting points of the layer **1** has an appropriate threshold value, and if the sum of measured data exceeds the threshold value, each of the connecting points will output a signal to the connecting points of layer **2**. Although the weight sensor input is shown as a single input, in general there will be a separate input from each weight sensor used. For example, if we the seat has four seat supports and if a strained measuring element is used on each support, what will be four data inputs to neural network.

The connecting points of the layer **2** comprises 20 points, and the 25 connecting points of the layer **1** are appropriately interconnected as the connecting points of the layer **2**. Similarly, each data is mutually correlated through the training process and weight determination as described above and in the above referenced neural network texts. Each of the 20 connecting points of the layer **2** has an appropriate threshold value, and if the sum of measured data exceeds the threshold value, each of the connecting points will output a signal to the connecting points of layer **3**.

The connecting points of the layer **3** comprises 3 points, and the connecting points of the layer **2** are interconnected at the connecting points of the layer **3** so that each data is mutually correlated as described above. If the sum of the outputs of the connecting points of layer **2** exceeds a threshold value, the connecting points of the latter **3** will output Logic values (100), (010), and (001) respectively, for example.

The threshold value of each connecting point is determined by multiplying weight coefficients and summing up the results in sequence, and the aforementioned training process is to determine a weight coefficient Wj so that the threshold value (ai) is a previously determined output.

$$ai=\Sigma Wj\cdot Xj(j=1 \text{ to } N)$$

wherein Wj is the weight coefficient,

Xj is the data and

N is the number of samples.

Based on this result of the training, the neural network **25** generates the weights for the coefficients of the correlation function or the algorithm (step S7).

At the time the neural network **25** has learned a suitable number of patterns of the training data, the result of the training is tested by the test data. In the case where the rate of correct answers of the seated-state detecting unit based on this test data is unsatisfactory, the neural network is further trained and the test is repeated. In this embodiment, the test was performed based on about 600,000 test patterns. When the rate of correct test result answers was at about 98%, the training was ended.

The neural network **25** has outputs **25***a*, **25***b* and **25***c*. Each of the outputs **25***a*, **25***b* and **25***c* outputs a of logic 0 or 1 to a gate circuit or algorithm **30**. Based on the signals from the outputs **25***a*, **25***b* and **25***c*, any on these combination (100), (010) and (001) is obtained. In another preferred embodiment, all data for the empty seat was removed from the training set and the empty seat case was determined based on the output of the weight sensor alone. This simplifies the neural network and improves its accuracy.

In this embodiment, the output (001) correspond to a vacant seat, a seat occupied by an inanimate object or a seat occupied by a pet (VACANT), the output (010) corresponds to a rear facing child seat (RFCS) or an abnormally seated passenger (ASP), and the output (100) corresponds to a normally seated passenger (NSP) or a forward facing child seat (FFCS).

The gate circuit (seated-state evaluation circuit) **30** can be implemented by an electronic circuit or by a computer algorithm by those skilled in the art and the details will not be presented here. The function of the gate circuit **30** is to remove the ambiguity that sometimes results when ultrasonic sensors and seat position sensors alone are used. This ambiguity is that it is sometimes difficult to differentiate between a rear facing child seat (RFCS) and an abnormally seated passenger (ASP), or between a normally seated passenger (NSP) and a forward facing child seat (FFCS). By the addition of one or more weight sensors in the function of acting as a switch when the weight is above or below 60 lbs., it has been found that this ambiguity can be eliminated. The gate circuit therefore takes into account the output of the neural network and also the weight from the weight sensor(s) as being above or below 60 lbs. and thereby separates the two cases just described and results in five discrete outputs.

Thus, the gate circuit **30** fulfills a role of outputting five kinds of seated-state evaluation signals, based on a combination of three kinds of evaluation signals from the neural network **25** and superimposed information from the weight sensor(s). The five seated-state evaluation signals are input to an airbag deployment determining circuit that is part of the airbag system and will not be described here. Naturally, as disclosed in the above reference patents and patent applications, the output of this system can also be used to activate a variety of lights or alarms to indicate to the operator of the vehicle the seated state of the passenger. Naturally, the system that has been here described for the passenger side is also applicable for the most part for the driver side.

An alternate and preferred method of accomplishing the function performed by the gate circuit is to use a modular neural network. In this case, the first level neural network is trained on determining whether the seat is occupied or vacant. The input to this neural network consists of all of the data points described above. Since the only function of this neural network is to ascertain occupancy, the accuracy of

this neural network is very high. If this neural network determines that the seat is not vacant, then the second level neural network determines the occupancy state of the seat.

In this embodiment, although the neural network **25** has been employed as an evaluation circuit, the mapping data of the coefficients of a correlation function may also be implemented or transferred to a microcomputer to constitute the valuation circuit (see Step **S8** in FIG. **6**).

According to the seated-state detecting unit of the present invention, the identification of a vacant seat (VACANT), a rear facing child seat (RFCS), a forward facing child seat (FFCS), a normally seated adult passenger (NSP), an abnormally seated adult passenger (ASP), can be reliably performed. Based on this identification, it is possible to control a component, system or subsystem in the vehicle. For example, a regulation valve which controls the inflation or deflation of an airbag may be controlled based on the evaluated identification of the occupant of the seat. This regulation valve may be of the digital or analog type. A digital regulation valve is one that is in either of two states, open or closed. The control of the flow is then accomplished by varying the time that the valve is open and closed, i.e., the duty cycle.

Moreover, the seated-state detecting unit described above may be used in a component adjustment system and method described below when the presence of a human being occupying the seat is detected.

The component adjustment system and methods in accordance with the invention automatically and passively adjust the component based on the morphology of the occupant of the seat. As noted above, the adjustment system may include the seated-state detecting unit described above so that it will be activated if the seated-state detecting unit detects that an adult or child occupant is seated on the seat, i.e., the adjustment system will not operate if the seat is occupied by a child seat, pet or inanimate objects. Obviously, the same system can be used for any seat in the vehicle including the driver seat and the passenger seat(s). This adjustment system may incorporated the same components as the seated-state detecting unit described above, i.e., the same components may constitute a part of both the seated-state detecting unit and the adjustment system, e.g., the weight measuring means.

The adjustment system described herein, although improved over the prior art, will at best be approximate since two people, even if they are identical in all other respects, may have a different preferred driving position or other preferred adjusted component location or orientation. A system that automatically adjusts the component, therefore, must learn from its errors. Thus, when a new occupant sits in the vehicle, for example, the system automatically estimates the best location of the component for that occupant and moves the component to that location, assuming it is not already at the best location. If the occupant changes the location, the system must remember that change and incorporate it into the adjustment the next time that person enters the vehicle and is seated in the same seat. Therefore, the system need not make a perfect selection the first time but it must remember the person and the position the component was in for that person. The system, therefore, makes one, two or three measurements of morphological characteristics of the occupant and then adjusts the component based on an algorithm. The occupant will correct the adjustment and the next time that the system measures the same measurements for those measurement characteristics, it will set the component to the corrected position. As such, preferred components for which the system in accordance with the invention is most useful are those which affect a driver of the vehicle and relate to the sensory abilities of the driver, i.e., the mirrors, the seat, the steering wheel and steering column and accelerator, clutch and brake pedals.

The first characteristic used is a measurement of the height of the occupant from the vehicle seat. This can be done by a sensor in the ceiling of the vehicle but this becomes difficult since, even for the same seat location, the head of the occupant will not be at the same angle with respect to the seat and therefore the angle to a ceiling—mounted sensor is in general unknown at least as long as only one ceiling mounted sensor is used. This problem can be solved if two or three sensors are used as described in more detail below. The simplest implementation is to place the sensor in the seat. In the '320 patent mentioned above, a rear impact occupant protection apparatus is disclosed which uses sensors mounted within the headrest. This same system can also be used to measure the height of the occupant from the seat and thus, for no additional cost assuming the rear impact occupant protection system described in the '320 patent is provided, the first measure of the occupant's morphology can be achieved. For some applications, this may be sufficient since it is unlikely that two operators will use the vehicle who have the same height. For other implementations, one or more additional measurements are used.

Referring now to FIG. **8**, an automatic adjustment system for adjusting a seat (which is being used only as an example of a vehicle component) is shown generally at **100** with a movable headrest **111** and ultrasonic sensor **120** and ultrasonic receiver **121** for measuring the height of the occupant of the seat. Power means such as motors **191**, **192**, and **193** connected to the seat for moving the base of the seat, control means such as a control circuit, system or module **150** connected to the motors and a headrest actuation mechanism using servomotors **160** and **170**, which may be servomotors, are also illustrated. The seat **110** and headrest **111** are shown in phantom. Vertical motion of the headrest **111** is accomplished when a signal is sent from control module **150** to servomotor **160** through a wire **131**. Servomotor **160** rotates lead screw **162** which engages with a threaded hole in member **164** causing it to move up or down depending on the direction of rotation of the lead screw **162**. Headrest support rods **165** and **166** are attached to member **164** and cause the headrest **111** to translate up or down with member **164**. In this manner, the vertical position of the headrest can be controlled as depicted by arrow A-A. Ultrasonic transmitter and receiver **120**, **121** may be replaced by other appropriate wave-generating and receiving devices, such as electromagnetic, active infrared transmitters and receivers.

Wire **132** leads from control module **150** to servomotor **170** which rotates lead screw **172**. Lead screw **172** engages with a threaded hole in shaft **173** which is attached to supporting structures within the seat shown in phantom. The rotation of lead screw **172** rotates servo motor support **161**, upon which servomotor **160** is situated, which in turn rotates headrest support rods **165** and **166** in slots **168** and **169** in the seat **110**. Rotation of the servomotor support **161** is facilitated by a rod **171** upon which the servo motor support **161** is positioned. In this manner, the headrest **111** is caused to move in the fore and aft direction as depicted by arrow B-B. Naturally there are other designs which accomplish the same effect in moving the headrest up and down and fore and aft.

The operation of the system is as follows. When an adult or child occupant is seated on a seat containing the headrest and control system described above as determined by the neural network **25**, the ultrasonic transmitter **120** emits

ultrasonic energy which reflects off of the head of the occupant and is received by receiver **121**. An electronic circuit in control module **150** contains a microprocessor which determines the distance from the head of the occupant based on the time between the transmission and reception of an ultrasonic pulse. Control module **150** may be within the same microprocessor as neural network **25** or separate therefrom. The headrest **111** moves up and down until it finds the top of the head and then the vertical position closest to the head of the occupant and then remains at that position. Based on the time delay between transmission and reception of an ultrasonic pulse, the system can also determine the longitudinal distance from the headrest to the occupant's head. Since the head may not be located precisely in line with the ultrasonic sensors, or the occupant may be wearing a hat, coat with a high collar, or may have a large hairdo, there may be some error in this longitudinal measurement.

When an occupant sits on seat **110**, the headrest **111** moves to find the top of the occupant's head as discussed above. This is accomplished using an algorithm and a microprocessor which is part of control circuit **150**. The headrest **111** then moves to the optimum location for rear impact protection as described in the above referenced '320 patent. Once the height of the occupant has been measured, another algorithm in the microprocessor in control circuit **150** compares the occupant's measured height with a table representing the population as a whole and from this table, the appropriate positions for the seat corresponding to the occupant's height is selected. For example, if the occupant measured 33 inches from the top of the seat bottom, this might correspond to a 85% human, depending on the particular seat and statistical tables of human measurements.

Careful study of each particular vehicle model provides the data for the table of the location of the seat to properly position the eyes of the occupant within the "eye-ellipse", the steering wheel within a comfortable reach of the occupant's hands and the pedals within a comfortable reach of the occupant's feet, based on his or her size, etc.

Once the proper position has been determined by control circuit **150**, signals are sent to motors **191**, **192**, and **193** to move the seat to that position, if such movement is necessary. That is, it is possible that the seat will be in the proper position so that movement of the seat is not required. As such, the position of the motors **191**,**192**,**193** and/or the position of the seat prior to occupancy by the occupant may be stored in memory so that after occupancy by the occupant and determination of the desired position of the seat, a comparison is made to determine whether the desired position of the seat deviates from the current position of the seat. If not, movement of the seat is not required. Otherwise, the signals are sent by the control circuit **150** to the motors. In this case, control circuit **150** would encompass a seat controller.

Instead of adjusting the seat to position the driver in an optimum driving position, or for use when adjusting the seat of a passenger, it is possible to perform the adjustment with a view toward optimizing the actuation or deployment of an occupant protection or restraint device. For example, after obtaining one or more morphological characteristics of the occupant, the processor can analyze them and determine one or more preferred positions of the seat, with the position of the seat being related to the position of the occupant, so that if the occupant protection device is deployed, the occupant will be in an advantageous position to be protected against injury by such deployment. In this case then, the seat is adjusted based on the morphology of the occupant view a view toward optimizing deployment of the occupant protection device. The processor is provided in a training or programming stage with the preferred seat positions for different morphologies of occupants.

Movement of the seat can take place either immediately upon the occupant sitting in the seat or immediately prior to a crash requiring deployment of the occupant protection device. In the latter case, if an anticipatory sensing arrangement is used, the seat can be positioned immediately prior to the impact, much in a similar manner as the headrest is adjusted for a rear impact as disclosed in the '320 patent referenced above.

If during some set time period after the seat has been positioned, the operator changes these adjustments, the new positions of the seat are stored in association with an occupant height class in a second table within control circuit **150**. When the occupant again occupies the seat and his or her height has once again been determined, the control circuit **150** will find an entry in the second table which takes precedence over the basic, original table and the seat returns to the adjusted position. When the occupant leaves the vehicle, or even when the engine is shut off and the door opened, the seat can be returned to a neutral position which provides for easy entry and exit from the vehicle.

The seat **110** also contains two control switch assemblies **180** and **182** for manually controlling the position of the seat **110** and headrest **111**. The seat control switches **180** permit the occupant to adjust the position of the seat if he or she is dissatisfied with the position selected by the algorithm. The headrest control switches **182** permit the occupant to adjust the position of the headrest in the event that the calculated position is uncomfortably close to or far from the occupant's head. A woman with a large hairdo might find that the headrest automatically adjusts so as to contact her hairdo. This adjustment she might find annoying and could then position the headrest further from her head. For those vehicles which have a seat memory system for associating the seat position with a particular occupant, which has been assumed above, the position of the headrest relative to the occupant's head could also be recorded. Later, when the occupant enters the vehicle, and the seat automatically adjusts to the recorded preference, the headrest will similarly automatically adjust (FIG. **17**B).

The height of the occupant, although probably the best initial morphological characteristic, may not be sufficient especially for distinguishing one driver from another when they are approximately the same height. A second characteristic, the occupant's weight, can also be readily determined from sensors mounted within the seat in a variety of ways as shown in FIG. **9** which is a perspective view of the seat shown in FIG. **8** with a displacement or weight sensor **200** shown mounted onto the seat. Displacement sensor **200** is supported from supports **202** and **204**. In general, displacement sensor **200**, or another non-displacement sensor, measures a physical state of a component affected by the occupancy of the seat. An occupying item of the seat will cause a force to be exerted downward and the magnitude of this force is representative of the weight of the occupying item. Thus, by measuring this force, information about the weight of the occupying item can be obtained. A physical state may be any force changed by the occupancy of the seat and which is reflected in the component, e.g., strain of a component, compression of a component, tension of a component.

Referring now to FIG. **9**A, which is a view of the apparatus of FIG. **9** taken along line **9**A-**9**A, seat **230** is constructed from a cushion or foam layer **232** which is supported by a spring system **234** which is in contact and/or

association with the displacement sensor **200**. As shown, displacement sensor **200** is underneath the spring system **234** but this relative positioning is not a required feature of the invention. The displacement sensor **200** comprises an elongate cable **205** retained at one end by support **210** and a displacement sensor **220** situated at an opposite end. This displacement sensor **220** can be any of a variety of such devices including, but not limited to, a linear rheostat, a linear variable differential transformer (LVDT), a linear variable capacitor, or any other length measuring device. Alternately, as shown in FIG. **9**C, the cable can be replaced with one or more springs **242** retained between supports **210** and the tension in the spring measured using a strain gage (conventional wire or foil or a SAW strain gage) or other force measuring device **244** or the strain in the seat support structure can be measured by appropriately placing strain gages on one or more of the seat supports as described in more detail below. The strain gage or other force measuring device could be arranged in association with the spring system **234** and could measure the deflection of the bottom surface of the cushion or foam layer **232**.

When a SAW strain gage **244** is used as part of weight sensor **200**, an interrogator **246** could be placed on the vehicle to enable wireless communication and/or power transfer to the SAW strain gage **244**. As such, when it is desired to obtain the force being applied by the occupying item on the seat, the interrogator **246** sends a radio signal to the SAW strain gage causing it to transmit a return signal with the measured strain of the spring **242**. Interrogator **246** is coupled to the processor used to determine the control of the vehicle component.

As shown in FIG. **9**D, one or more SAW strain gages **248** could also be placed on the bottom surface of the cushion or foam layer **232** in order to measure the deflection of the bottom surface which is representative of the weight of the occupying item to the seat. An interrogator **249** could also be used in this embodiment.

One seat design is illustrated in FIG. **9**. Similar weight measurement systems can be designed for other seat designs. Also, some products are available which can approximately measure weight based on pressure measurements made at or near the upper seat surface **236**. It should be noted that the weight measured here will not be the entire weight of the occupant since some of the occupant's weight will be supported by his or her feet which are resting on the floor or pedals. As noted above, the weight may also be measured by the weight sensor(s) **6** and **7** described above in the seated-state detecting unit.

As weight is placed on the seat surface **236**, it is supported by spring **234** which deflects downward causing cable **205** of the sensor **200** to begin to stretch axially. Using a LVDT as an example of length measuring device **220**, the cable **205** pulls on rod **221** tending to remove rod **221** from cylinder **223** (FIG. **9**B). The movement of rod **221** out of cylinder **223** is resisted by a spring **222** which returns the rod **221** into the cylinder **223** when the weight is removed from the seat surface **236**. The amount which the rod **221** is removed from the cylinder **223** is measured by the amount of coupling between the windings **226** and **227** of the transformer as is well understood by those skilled in the art. LVDT's are commercially available devices. In this matter, the deflection of the seat can be measured which is a measurement of the weight on the seat. The exact relationship between weight and LVDT output is generally determined experimentally for this application.

SAW strain gages could also be used to determine the downward deflection of the spring **234** and the deflection of the cable **205**.

By use of a combination of weight and height, the driver of the vehicle can in general be positively identified among the class of drivers who operate the vehicle. Thus, when a particular driver first uses the vehicle, the seat will be automatically adjusted to the proper position. If the driver changes that position within a prescribed time period, the new seat position will be stored in the second table for the particular driver's height and weight. When the driver reenters the vehicle and his or her height and weight are again measured, the seat will go to the location specified in the second table if one exists. Otherwise, the location specified in the first table will be used.

The system described above is based on the assumption that the occupant will be satisfied with one seat position throughout an extended driving trip. Studies have shown that for extended travel periods that the comfort of the driver can be improved through variations in the seat position. This variability can be handled in several ways. For example, the amount and type of variation preferred by an occupant of the particular morphology can be determined through case studies and focus groups. If it is found, for example, that the 50 percentile male driver prefers the seat back angle to vary by 5 degrees sinusodially with a one-hour period, this can be programmed to the system. Since the system knows the morphology of the driver it can decide from a lookup table what is the best variability for the average driver of that morphology. The driver then can select from several preferred possibilities if, for example, he or she wishes to have the seat back not move at all or follow an excursion of 10 degrees over two hours.

This system provides an identification of the driver based on two morphological characteristics which is adequate for most cases. As additional features of the vehicle interior identification and monitoring system described in the above referenced patent applications are implemented, it will be possible to obtain additional morphological measurements of the driver which will provide even greater accuracy in driver identification. Two characteristics may not be sufficient to rely on for theft and security purposes, however, many other driver preferences can still be added to seat position with this level of occupant recognition accuracy. These include the automatic selection of a preferred radio station, vehicle temperature, steering wheel and steering column position, etc.

One advantage of using only the height and weight is that it avoids the necessity of the seat manufacturer from having to interact with the headliner manufacturer, or other component suppliers, since all of the measuring transducers are in the seat. This two characteristic system is generally sufficient to distinguish drivers that normally drive a particular vehicle. This system costs little more than the memory systems now in use and is passive, i.e., it does not require action on the part of the occupant after his initial adjustment has been made.

Instead of measuring the height and weight of the occupant, it is also possible to measure a combination of any two morphological characteristics and during a training phase, derive a relationship between the occupancy of the seat, e.g., adult occupant, child occupant, etc., and the data of the two morphological characteristic. This relationship may be embodied within a neural network so that during use, by measuring the two morphological characteristics, the occupancy of the seat can be determined.

Naturally, there are other methods of measuring the height of the driver such as placing the transducers at other locations in the vehicle. Some alternatives are shown in FIG. **10** which is a side plan view wherein two height measuring sensors **320**, **321** are shown, sensor **321** being mounted into the headliner above the occupant's head and the other sensor **320** being mounted onto the A-pillar. A sensor as used herein is the combination of two transducers (a transmitter and a receiver) or one transducer which can both transmit and receive. The headliner is the trim which provides the interior surface to the roof of the vehicle and the A-pillar is the roof-supporting member which is on either side of the windshield and on which the front doors are hinged. These transducers may already be present because of other implementations of the vehicle interior identification and monitoring system described in the above referenced patent applications. In this case, the use of both transducers provides a more accurate determination of location of the head of the driver. Using transducer **321** alone, the exact position of the head is ambiguous since the transducer measures the distance to the head regardless of what direction the head is. By knowing the distance from the head to transducer **320**, the ambiguity is substantially reduced. This argument is of course dependent on the use of ultrasonic transducers. Optical transducers using CCD or CMOS arrays are now becoming price competitive and, as pointed out in the above referenced patent applications, will be the technology of choice for interior vehicle monitoring. A single CCD array of 160 by 160 pixels, for example, coupled with the appropriate pattern recognition software, can be used to form an image of the head of an occupant and accurately locate the head for the purposes of this invention.

FIG. **10** also illustrates a system where the seatbelt **330** has an adjustable upper anchorage point **331** which is automatically adjusted by a motor **332** to a location optimized based on the height of the occupant. The calculations for this feature and the appropriate control circuitry can also be located in control module **301** or elsewhere if appropriate.

Many luxury automobiles today have the ability to control the angle of the seat back as well as a lumbar support. These additional motions of the seat can also be controlled by the seat adjustment system in accordance with the invention. FIG. **11** is a view of the seat of FIG. **8** showing motors **481** and **482** for changing the tilt of the seat back and the lumbar support. Three motors **482** are used to adjust the lumbar support in this implementation. The same procedure is used for these additional motions as described for FIG. **8** above.

An initial table is provided based on the optimum positions for various segments of the population. For example, for some applications the table may contain a setting value for each five percentile of the population for each of the 6 possible seat motions, fore and aft, up and down, total seat tilt, seat back angle, lumbar position, and headrest position for a total of 120 table entries. The second table similarly would contain the personal preference modified values of the 6 positions desired by a particular driver.

In FIG. **8**, the ultrasonic transducers **120** and **121** were described as one being a transmitter and the other being a receiver. For some applications, it is desirable to use both transducers as both transducers and receivers. Similarly, a third combination transmitter and receiver **122** may also be utilized as shown in FIG. **11**. This arrangement permits many of the advantages of a phased array system to be achieved.

The angular resolution of a transducer is proportional to the ratio of the wavelength to the diameter of the transmitter. Once three transmitters and receivers are used, the approximate equivalent single transmitter and receiver is one which has a diameter approximately equal to the shortest distance between any pair of transducers. In this case, the equivalent diameter is equal to the distance between transmitter **120** or **121** and **122**. This provides far greater resolution and, by controlling the phase between signals sent by the transmitters, the direction of the equivalent ultrasonic beam can be controlled. Thus, the head of the driver can be scanned with great accuracy and a map made of the occupant's head. Using this technology plus an appropriate pattern recognition algorithm, such as a neural network, an accurate location of the driver's head can be found even when the driver's head is partially obscured by a hat, coat, or hairdo. This also provides at least one other identification morphological characteristic which can be used to further identify the occupant, namely the diameter of the driver's head.

With knowledge of the weight of an occupant, additional improvements can be made to automobile and truck seat designs. In particular, the stiffness of the seat can be adjusted so as to provide the same level of comfort for light and for heavy occupants. The damping of occupant motions, which heretofore has been largely neglected, can also be readily adjusted as shown on FIG. **12** which is a view of the seat of FIG. **8** showing one of several possible arrangements for changing the stiffness and the damping of the seat. In the seat bottom **520**, there is a container **515**, the conventional foam and spring design has been replaced by an inflated rectangular container very much like an air mattress which contains a cylindrical inner container **518** which is filled with an open cell urethane foam. An adjustable orifice **525** connects the two container **515**,**518** so that air can flow in a controlled manner therebetween. The amount of opening of orifice **525** is controlled by control circuit **150**. A small air compressor **555** controls the pressure in container **515** under control of the control circuit **150**. A pressure transducer **560** monitors the pressure within container **515** and inputs this information into control circuit **150**.

The operation of the system is as follows. When an occupant sits on the seat, pressure initially builds up in the seat container **515** which gives an accurate measurement of the weight of the occupant. Control circuit **150**, using an algorithm and a microprocessor, then determines an appropriate stiffness for the seat and adds pressure to achieve that stiffness. The pressure equalizes between the two containers **515** and **518** through the flow of air through orifice **525**. Control circuit **150** also determines an appropriate damping for the occupant and adjusts the orifice **525** to achieve that damping. As the vehicle travels down the road and the road roughness causes the seat to move up and down, the inertial force on the seat by the occupant causes the air pressure to rise and fall in container **518** and also, but, much less so, in container **515** since the occupant sits mainly above container **518** and container **515** is much larger than container **518**. The major deflection in the seat takes place first in container **518** which pressurizes and transfers air to container **515** through orifice **525**. The size of the orifice opening determines the flow rate between the two containers and therefore the damping of the motion of the occupant. Since this opening is controlled by control circuit **150**, the amount of damping can thereby also be controlled. Thus, in this simple structure, both the stiffness and damping can be controlled to optimize the seat for a particular driver. Naturally, if the driver does not like the settings made by control circuit **150**, he or she can change them to provide a stiffer or softer ride.

The stiffness of a seat is the change in force divided by the change in deflection. This is important for many reasons, one of which is that it controls the natural vibration frequency of

the seat occupant combination. It is important that this be different from the frequency of vibrations which are transmitted to the seat from the vehicle in order to minimize the up and down motions of the occupant. The damping is a force which opposes the motion of the occupant and which is dependent on the velocity of relative motion between the occupant and the seat bottom. It thus removes energy and minimizes the oscillatory motion of the occupant. These factors are especially important in trucks where the vibratory motions of the driver's seat, and thus the driver, have caused many serious back injuries among truck drivers.

In FIG. **12**, the airbag or bladder **515** which interacts with the occupant is shown with a single chamber. Naturally, bladder **515** can be composed of multiple chambers **515***a*, **515***b*, **515***c*, and **515***d* as shown in FIG. **12**A. The use of multiple chambers permits the weight distribution of the occupant to be determined if a separate pressure transducer is used in each cell of the bladder. Such a scheme gives the opportunity of determining to some extent the position of the occupant on the seat or at least the position of the center of gravity of the occupant. Naturally, more than four cells could be used.

In the description above, the air was use as the fluid to fill the bladder **515**. In some cases, especially where damping and natural frequency control is not needed, another fluid such as a liquid or jell could be used to fill the bladder.

In an automobile, there is an approximately fixed vertical distance between the optimum location of the occupant's eyes and the location of the pedals. The distant from a driver's eyes to his or her feet, on the other hand, is not the same for all people. An individual driver now compensates for this discrepancy by moving the seat and by changing the angle between his or hers legs and body. For both small and large drivers, this discrepancy cannot be fully compensated for and as a result, their eyes are not appropriately placed. A similar problem exists with the steering wheel. To help correct these problems, the pedals and steering column should be movable as illustrated in FIG. **13** which is a plan view similar to that of FIG. **10** showing a driver and driver seat with an automatically adjustable steering column and pedal system which is adjusted based on the morphology of the driver. In FIG. **13**, a motor **650** is connected to and controls the position of the steering column and another motor **660** is connected to and controls the position of the pedals. Both motors **650**,**660** are coupled to and controlled by control circuit **150** wherein now the basic table of settings includes values for both the pedals and steering column locations.

As various parts of the vehicle interior identification and monitoring system described in the above reference patent applications are implemented, a variety of transmitting and receiving transducers will be present in the vehicle passenger compartment. If several of these transducers are ultrasonic transmitters and receivers, they can be operated in a phased array manner, as described above for the headrest, to permit precise distance measurements and mapping of the components of the passenger compartment. This is illustrated in FIG. **14** which is a perspective view of the interior of the passenger compartment showing a variety of transmitters and receivers, **700**-**706** which can be used in a phased array system. In addition, information can be transmitted between the transducers using coded signals in a ultrasonic network through the vehicle compartment airspace. If one of these sensors is an optical CCD or CMOS array, the location of the driver's eyes can be accurately determined and the results sent to the seat ultrasonically. Obviously, many other possibilities exist.

The eye ellipse discussed above is illustrated at **810** in FIG. **15**, which is a view similar to FIG. **1**, showing the occupant's eyes and the seat adjusted to place the eyes at a particular vertical position for proper viewing through the windshield and rear view mirror. Many systems are now under development to improve vehicle safety and driving ease. For example, right vision systems are being tested which project an enhanced image of the road ahead of the vehicle onto the windshield in a "heads-up display". The main problem with the systems now being tested is that the projected image does not precisely overlap the image as seen through the windshield. This parallax causes confusion in the driver and can only be corrected if the location of the driver's eyes is accurately known. One method of solving this problem is to use the passive seat adjustment system described herein to place the occupant's eyes at the optimum location as described above. Once this has been accomplished, in addition to solving the parallax problem, the eyes are properly located with respect to the rear view mirror **820** and little if any adjustment is required in order for the driver to have the proper view of what is behind the vehicle.

Several systems are in development for determining the location of an occupant and modifying the deployment of the airbag based of his or her position. These systems are called "smart airbags". The passive seat control system in accordance with this invention can also be used for this purpose as illustrated in FIG. **16**. This figure is a view similar to FIG. **8** showing an inflated airbag **900** and an arrangement for controlling both the flow of gas into and out of the airbag during a crash. The determination is made based on height sensors **120**, **121** and **122** located in the headrest, a weight sensor **200** in the seat and the location of the seat which is known by control circuit **150** (See, FIGS. **8**, **9** and **9**A). Other smart airbags systems rely only on the position of the occupant determined from various position sensors using ultrasonics or optical sensors.

The weight sensor coupled with the height sensor and the occupant's velocity relative to the vehicle, as determined by the occupant position sensors, provides information as to the amount of energy which the airbag will need to absorb during the impact of the occupant with the airbag. This, along with the location of the occupant relative to the airbag, is then used to determine the amount of gas which is to be injected into the airbag during deployment and the size of the exit orifices which control the rate of energy dissipation as the occupant is interacting with the airbag during the crash. For example, if an occupant is particularly heavy then it is desirable to increase the amount of gas, and thus the initial pressure, in the airbag to accommodate the larger force which will be required to arrest the relative motion of the occupant. Also, the size of the exit orifices should be reduced, since there will be a larger pressure tending to force the gas out of the orifices, in order to prevent the bag from bottoming out before the occupant's relative velocity is arrested. Similarly, for a small occupant the initial pressure would be reduced and the size of the exit orifices increased. If, on the other hand, the occupant is already close to the airbag then the amount of gas injected into the airbag needs to be reduced.

There are many ways of varying the amount of gas injected into the airbag some of which are covered in the patent literature and include, for example, inflators where the amount of gas generated and the rate of generation is controllable. For example, in a particular hybrid inflator manufactured by the Allied Signal Corporation, two pyrotechnic charges are available to heat the stored gas in the inflator. Either or both of the pyrotechnic charges can be

ignited and the timing between the ignitions can be controlled to significantly vary the rate of gas flow to the airbag.

The flow of gas out of the airbag is traditionally done through fixed diameter orifices placed in the bag fabric. Some attempts have been made to provide a measure of control through such measures as blowout patches applied to the exterior of the airbag. Other systems were disclosed in U.S. patent application Ser. No. 07/541,464 filed Feb. 9, 1989, now abandoned. FIG. **16**A illustrates schematically an inflator **910** generating gas to fill airbag **900** through control valve **920**. The flow of gas out of airbag **900** is controlled by exit control valve **930**. The valve **930** can be implemented in many different ways including, for example, a motor operated valve located adjacent the inflator and in fluid communication with the airbag or a digital flow control valve as discussed above. When control circuit **150** determines the size and weight of the occupant, the seat position and the relative velocity of the occupant, it then determines the appropriate opening for the exit valve **930**, which is coupled to the control circuit **150**. A signal is then sent from control circuit **150** to the motor controlling this valve which provides the proper opening.

In a like manner, other parameters can also be adjusted, such as the direction of the airbag, by properly positioning the angle and location of the steering wheel relative to the driver. If seatbelt pretensioners are used, the amount of tension in the seatbelt or the force at which the seatbelt spools out, for the case of force limiters, could also be adjusted based on the occupant morphological characteristics determined by the system of this invention.

Once the morphology of the driver and the seat position is known, many other objects in the vehicle can be automatically adjusted to conform to the occupant. An automatically adjustable seat armrest, a cup holder, the cellular phone, or any other objects with which the driver interacts can be now moved to accommodate the driver. This is in addition to the personal preference items such as the radio station, temperature, etc. discussed above.

Once the system of this invention is implemented, additional features become possible such as a seat which automatically makes slight adjustments to help alleviate fatigue or to account for a change of position of the driver in the seat, or a seat which automatically changes position slightly based on the time of day. Many people prefer to sit more upright when driving at night, for example. Other similar improvements based on knowledge of the occupant morphology will now become obvious to those skilled in the art.

In the above-described component adjustment systems and methods, one of the characteristics of the occupying item that may be measured is the weight. Several non-limiting examples of weight measuring apparatus will now be described which may be used in the above-described systems and methods.

In a first embodiment of a weight measuring apparatus shown in FIG. **18**, four strain gage weight sensors or transducers are used, two being illustrated at **1010** and **1011** on one side of a bracket of the support structure of the seat and the other two being at the same locations on another bracket of the support (i.e., hidden on the corresponding locations on the other side of the support). The support structure of the seat supports the seat on a substrate such as a floor pan of the vehicle. Each of the strain gage transducers **1010**,**1011** also contains electronic signal conditioning apparatus, e.g., amplifiers, analog to digital converters, filters etc., which is associated such that output from the transducers is a digital signal. This electronic signal travels from transducer **1010** to transducer **1011** through a wire **1020**. Similarly, wire **1021** transmits the output from transducers **1010** and **1011** to the next transducer in the sequence (one of the hidden transducers). Additionally, wire **1022** carries the output from these three transducers toward the fourth transducer (the other hidden transducer) and wire **1023** finally carries all four digital signals to an electronic control system or module **1030**. These signals from the transducers **1010**,**1011** are time or frequency division multiplexed as is well known in the art. The seat position is controlled by motors **1040** as described in detail in U.S. Pat. No. 5,179,576, which is incorporated herein by reference. Finally, the seat is bolted onto the support structure through bolts not shown which attach the seat through holes **1050** in the brackets.

By placing the signal conditioning electronics, analog to digital converters, and other appropriate electronic circuitry adjacent the strain gage element, the four transducers can be daisy chained or otherwise attach together and only a single wire is required to connect all of the transducers to the control module **1030** as well as provide the power to run the transducers and their associated electronics.

The control system **1030**, e.g., a microprocessor, is arranged to receive the digital signals from the transducers **1010**,**1011** and determine the weight of the occupying item of the seat based thereon. In other words, the signals from the transducers **1010**,**1011** are processed by the control system **1030** to provide an indication of the weight of the occupying item of the seat, i.e., the force exerted by the occupying item on the seat support structure.

A typical manually controlled seat structure is illustrated in FIG. **19** and described in greater detail in U.S. Pat. No. 4,285,545. The seat **1056** (only the frame of which is shown) is attached to a pair of slide mechanisms **1058** in the rear thereof through support members such as rectangular tubular structures **1060** angled between the seat **1056** and the slide mechanisms **1058**. The front of the seat **1056** is attached to the vehicle (more particularly to the floor pan) through another support member such as a slide member **1062**, which is engaged with a housing **1064**. Slide mechanisms **1058**, support members **1060**, slide member **1062** and housing **1064** constitute the support structure for mounting the seat on a substrate, i.e., the floor pan. Strain gage transducers are located for this implementation at **1065** and **1066**, strain gage transducer **1065** being mounted on each tubular structure **1060** (only one of which is shown) and strain gage transducer **1066** being mounted on slide member **1062**. When an occupying item is situated on the seat cushion (not shown), each of the support members **1060** and **1062** are deformed or strained. This strain is measured by transducers **1065** and **1066**, respectively, to enable a determination of the weight of the item occupying the seat. More specifically, a control system or module or other compatible processing unit (not shown) is coupled to the strain gage transducers **1065**,**1066**, e.g., via electrical wires (not shown), to receive the measured strain and utilize the measured strain to determine the weight of the occupying item of the seat. The determined weight, or the raw measured strain, may be used to control a vehicular component such as the airbag.

Support members **1060** are substantially vertically oriented and are preferably made of a sufficiently rigid, non-bending component.

FIG. **19**A illustrates an alternate arrangement for the seat support structures wherein a gusset **1068** has been added to bridge the angle on the support member **1060**. Strain gage transducer **1069** is placed on this gusset **1068**. Since the gusset **1068** is not a supporting member, it can be made considerably thinner than the seat support member **1060**. As

the seat is loaded by an occupying item, the seat support member **1060** will bend. Since the gusset **1068** is relatively weak, greater strain will occur in the gusset **1068** than in the support member **1060**. The existence of this greater strain permits more efficient use of the strain gage dynamic range thus improving the accuracy of the weight measurement.

FIG. **19**B illustrates a seat transverse support member **1070** of the seat shown in FIG. **19**, which is situated below the base cushion and extends between opposed lateral sides of the seat. This support member **1070** will be directly loaded by the vehicle seat and thus will provide an average measurement of the force exerted or weight of the occupying item. The deflection or strain in support member **1070** is measured by a strain gage transducer **1072** mounted on the support member **1070** for this purpose. In some applications, the support member **1070** will occupy the entire space fore and aft below the seat cushion. Here it is shown as a relatively narrow member. The strain gage transducer **1072** is coupled, e.g., via an electrical wire (not shown), to a control module or other processing unit (not shown) which utilizes the measured strain to determine the weight of the occupying item of the seat.

In FIG. **19**, the support members **1060** are shown as rectangular tubes having an end connected to the seat **1056** and an opposite end connected to the slide mechanisms **1058**. In the constructions shown in FIGS. **20**A-**20**C, the rectangular tubular structure has been replaced by a circular tube where only the lower portion of the support is illustrated. FIGS. **20**A-**20**C show three alternate ways of improving the accuracy of the strain gage system, i.e., the accuracy of the measurements of strain by the strain gage transducers. Generally, a reduction in the stiffness of the support member to which the strain gage transducer is mounted will concentrate the force and thereby improve the strain measurement. There are several means disclosed below to reduce the stiffness of the support member. These means are not exclusive and other ways to reduce the stiffness of the support member are included in the invention and the interpretation of the claims.

In each illustrated embodiment, the transducer is represented by **1065** and the substantially vertically oriented support member corresponding to support member **1060** in FIG. **19** has been labeled **1060**A. In FIG. **20**A, the tube support member **1060**A has been cut to thereby form two separate tubes having longitudinally opposed ends and an additional tube section **1074** is connected, e.g., by welding, to end portions of the two tubes. In this manner, a more accurate tube section **1074** can be used to permit a more accurate measurement of the strain by transducer **1065**, which is mounted on tube section **1074**.

In FIG. **20**B, a small circumferential cut has been made in tube support member **1060**A so that a region having a smaller circumference than a remaining portion of the tube support member **1060**A is formed. This cut is used to control the diameter of the tube support member **1060**A at the location where strain gage transducer **1065** is measuring the strain. In other words, the strain gage transducer **1065** is placed at a portion wherein the diameter thereof is less than the diameter of remaining portions of the tube support member **1060**A. The purpose of this cut is to correct for manufacturing variations in the diameter of the tube support member **1060**A. The magnitude of the cut is selected so as to not significantly weaken the structural member but instead to control the diameter tolerance on the tube so that the strain from one vehicle to another will be the same for a particular loading of the seat.

In FIG. **20**C, a small hole **1078** is made in the tube support member **1060**A adjacent the transducer **1065** to compensate for manufacturing tolerances on the tube support member **1060**A.

From this discussion, it can be seen that all three techniques have as their primary purpose to provide increase the accuracy of the strain in the support member corresponding to weight on the vehicle seat. Naturally, the preferred approach would be to control the manufacturing tolerances on the support structure tubing so that the variation from vehicle to vehicle is minimized. For some applications where accurate measurements of weight are desired, the seat structure will be designed to optimize the ability to measure the strain in the support members and thereby to optimize the measurement of the weight of the occupying item. The inventions disclosed herein, therefore, are intended to cover the entire seat when the design of the seat is such as to be optimized for the purpose of strain gage weight sensing and alternately for the seat structure when it is so optimized.

Although strain measurement devices have been discussed above, pressure measurement systems can also be used in the seat support structure to measure the weight on the seat. Such a system is illustrated in FIG. **21**. A general description of the operation of this apparatus is disclosed in U.S. Pat. No. 5,785,291, which is incorporated herein by reference. In that patent, the vehicle seat is attached to the slide mechanism by means of bolts **1084**. Between the seat and the slide mechanism, a shock-absorbing washer has been used for each bolt. In the present invention, this shock-absorbing washer has been replaced by a sandwich construction consisting of two washers of shock absorbing material **1080** with a pressure sensitive material **1082** sandwiched in between. A variety of materials can be used for the pressure sensitive material **1082**, which generally work on either the capacitance or resistive change of the material as it is compressed. The wires from this material leading to the electronic control system are not shown in this view. The pressure sensitive material is coupled to the control system, e.g., a microprocessor, and provides the control system with an indication of the pressure applied by the seat on the slide mechanism which is related to the weight of the occupying item of the seat. Generally, material **1082** is constructed with electrodes on the opposing faces such that as the material is compressed, the spacing between the electrodes is decreased. This spacing change thereby changes both the resistive and the capacitance of the sandwich which can be measured and which is a function of the compressive force on the material. Measurement of the change in capacitance of the sandwich, i.e., two spaced apart conductive members, is obtained by any method known to those skilled in the art, e.g., connecting the electrodes in a circuit with a source of alternating or direct current. The conductive members may be made of a metal. The use of such a pressure sensor is not limited to the illustrated embodiment wherein the shock absorbing material **1080** and pressure sensitive material **1082** are placed around bolt **1084**. It is also not limited to the use or incorporation of shock absorbing material in the implementation.

FIG. **21**A shows a substitute construction for the bolt **1084** in FIG. **21** and which construction is preferably arranged in connection with the seat and the adjustment slide mechanism. A bolt-like member, hereinafter referred to as a stud **400**, is threaded **402** on both ends with a portion remaining unthreaded between the ends. A SAW strain measuring device including a SAW strain gage **404** and antenna **406** is arranged on the center unthreaded section of the stud **400** and the stud **400** is attached at its ends to the seat and the

slide mechanism using appropriate threaded nuts. Based on the particular geometry of the SAW device used, the stud **400** can result in as little as a 3 mm upward displacement of the seat compared to a normal bolt mounting system. No wires are required to attach the SAW device to the stud **400**. The total length of stud **400** may be as little as 1 inch. In operation, an interrogator **408** transmits a radio frequency pulse at for example, 925 MHz which excites the antenna **406** associated with the SAW strain gage **404**. After a delay caused by the time required for the wave to travel the length of the SAW device, a modified wave is re-transmitted to the interrogator **408** providing an indication of the strain and thus a representative value of the weight of an object occupying the seat. For a seat which is normally bolted to the slide mechanism with four bolts, at least four SAW strain measuring devices or sensors would be used. Each conventional bolt could thus be replaced by a stud as described above. Naturally, since the individual SAW devices are very small, multiple such devices can be placed on the stud to provide multiple redundant measurements or to permit the stud to be arbitrarily located with at least one SAW device always within direct view of the interrogator antenna.

To avoid potential problems with electromagnetic interference, the stud **400** may be made of a non-metallic, possibly composite, material which would not likely cause or contribute to any possible electromagnetic wave interference. The stud **400** could also be modified for use as an antenna.

With respect to the frequency of interrogation, if the seat is unoccupied then the frequency of interrogation can be substantially reduced in comparison to when the seat is occupied. For an occupied seat, information as to the identity and/or category and position of an occupying item of the seat can be obtained through the use of multiple weight sensors. For this reason, and due to the fact that during pre-crash event the position of an occupying item of the seat may be changing rapidly, interrogations as frequently as once every 10 milliseconds or even faster can be desirable. This would also enable a distribution of the weight being applied to the seat being obtained which provides an estimation of the position of the object occupying the seat. Using pattern recognition technology, e.g., a trained neural network, sensor fusion, fuzzy logic, etc., the identification of the object can be ascertained based on the determined weight and/or determined weight distribution.

Although each of the SAW devices can be interrogated and/or powered using wireless means, in some cases, it may be desirable to supply power to and or obtained information from such devices using wires.

In FIG. **22**, which is a view of a seat attachment structure described in U.S. Pat. No. 5,531,503, where a more conventional strain gage load cell design designated **1100** is utilized. One such load cell design **1100** is illustrated in detail in FIG. **22**A.

A cantilevered beam load cell design using a half bridge strain gage system **1110** is shown in FIG. **22**A. Fixed resistors mounted within the electronic package, which is not shown in this drawing, provide the remainder of the whetstone bridge system. The half bridge system is frequently used for economic reasons and where some sacrifice in accuracy is permissible. The load cell **110** includes a member on which the strain gage **1110** is situated. The strain gage **1100** includes strain-measuring elements **1112** and **1114** arranged on the load cell. The longitudinal element **1112** measures the tensile strain in the beam when it is loaded by the seat and its contents, not shown, which is attached to end **1122** of bolt **1120**. The load cell is mounted to the vehicle or other substrate using bolt **1130**. Temperature compensation is achieved in this system since the resistance change in strain elements **1112** and **1114** will vary the same amount with temperature and thus the voltage across the portions of the half bridge will remain the same. The strain gage **1100** is coupled to a control system (e.g., a microprocessor-not shown) via wires **1124** and receives the measured tensile strain and determines the weight of an occupying item of the seat based thereon.

One problem with using a cantilevered load cell is that it imparts a torque to the member on which it is mounted. One preferred mounting member on an automobile is the floor-pan which will support significant vertical loads but is poor at resisting torques since floor-pans are typically about 1 mm (0.04 inches) thick. This problem can be overcome through the use of a simply supported load cell design designated **1200** as shown in FIG. **22**B.

In FIG. **22**B, a full bridge strain gage system **1210** is used with all four elements **1212**,**1214** mounted on the top of a beam **1205**. Elements **1212** are mounted parallel to the beam **1205** and elements **1214** are mounted perpendicular to it. Since the maximum strain is in the middle of the beam **1205**, strain gage **1210** is mounted close to that location. The load cell, shown generally as **1200**, is supported by the floor pan, not shown, at supports **1230** that are formed by bending the beam **1205** downward at its ends. Fasteners **1220** fit through holes **1222** in the beam **1205** and serve to hold the load cell **1200** to the floor pan without putting significant forces on the load cell **1200**. Holes are provided in the floor-pan for bolt **1240** and for fasteners **1220**. Bolt **1240** is attached to the load cell **1200** through hole **1250** of the beam **1205** which serves to transfer the force from the seat to the load cell **1200**.

The electronics package is potted within hole **1262** using urethane potting compound **1244** and includes signal conditioning circuits, a microprocessor with integral ADCs **1280** and a flex circuit **1275** (FIG. **22**C). The flex circuit **1275** terminates at an electrical connector **1290** for connection to other vehicle electronics, e.g., a control system. The beam **1205** is slightly tapered at location **1232** so that the strain is constant in the strain gage.

Although thus far only beam type load cells have been described, other geometries can also be used. One such geometry is a tubular type load cell. Such a tubular load cell is shown generally at **1300** in FIG. **22**D and instead of an elongate beam, it includes a tube. It also comprises a plurality of strain sensing elements **1310** for measuring tensile and compressive strains in the tube as well as other elements, not shown, which are placed perpendicular to the elements **1310** to provide for temperature compensation. Temperature compensation is achieved in this manner, as is well known to those skilled in the art of the use of strain gages in conjunction with a whetstone bridge circuit, since temperature changes will affect each of the strain gage elements identically and the total effect thus cancels out in the circuit. The same bolt **1340** can be used in this case for mounting the load cell to the floor-pan and for attaching the seat to the load cell.

Another alternate load cell design shown generally in FIG. **22**E as **1400** makes use of a torsion bar **1410** and appropriately placed torsional strain sensing elements **1420**. A torque is imparted to the bar **1410** by means of lever **1430** and bolt **1440** which attaches to the seat structure not shown. Bolts **1450** attach the mounting blocks **1460** at ends of the torsion bar **1410** to the vehicle floor-pan.

The load cells illustrated above are all preferably of the foil strain gage type. Other types of strain gages exist which

would work equally which include wire strain gages and strain gages made from silicon. Silicon strain gages have the advantage of having a much larger gage factor and the disadvantage of greater temperature effects. For the high-volume implementation of this invention, silicon strain gages have an advantage in that the electronic circuitry (signal conditioning, ADCs, etc.) can be integrated with the strain gage for a low cost package. Other strain gage materials and load cell designs may, of course, be incorporated within the teachings of this invention. In particular, a surface acoustical wave (SAW) strain gage can be used in place of conventional wire, foil or silicon strain gages and the strain measured either wirelessly or by a wire connection. For SAW strain gages, the electronic signal conditioning can be associated directly with the gage or remotely in an electronic control module as desired. For SAW strain gages, the problems discussed above with low signal levels requiring bridge structures and the methods for temperature compensation may not apply. Generally, SAW strain gages are more accurate that other technologies but may require a separate sensor to measure the temperature for temperature compensation depending on the material used. Materials that can be considered for SAW strain gages are quartz, lithium niobate, lead zirconate, lead titenate, zinc oxide, polyvinylidene fluoride and other piezoelectric materials.

Many seat designs have four attachment points for the seat structure to attach to the vehicle. Since the plane of attachment is determined by three points, the potential exists for a significant uncertainty or error to be introduced. This problem can be compounded by the method of attachment of the seat to the vehicle. Some attachment methods using bolts, for example, can introduce significant strain in the seat supporting structure. Some compliance therefore must be introduced into the seat structure to reduce these attachment induced stresses to a minimum. Too much compliance, on the other hand, can significantly weaken the seat structure and thereby potentially cause a safety issue. This problem can be solved by rendering the compliance section of the seat structure highly nonlinear or significantly limiting the range of the compliance. One of the support members, for example, can be attached to the top of the seat structure through the use of the pinned joint wherein the angular rotation of the joint is severely limited. Methods will now be obvious to those skilled in the art to eliminate the attachment induced stress and strain in the structure which can cause inaccuracies in the strain measuring system.

In the examples illustrated above, strain measuring elements have been shown at each of the support members. This of course is necessary if an accurate measurement of the weight of the occupying item of the seat is to be determined. For this case, typically a single value is inputted into the neural network representing weight. Experiments have shown, however, for the four strain gage transducer system, that most of the weight and thus most of the strain occurs in the strain elements mounted on the rear seat support structural members. In fact, about 85 percent of the load is typically carried by the rear supports. Little accuracy is lost therefore if the forward strain measuring elements are eliminated. Similarly, for most cases, the two rear mounted support strain elements measure approximately the same strain. Thus, the information represented by the strain in one rear seat support is sufficient to provide a reasonably accurate measurement of the weight of the occupying item of the seat.

If a system consisting of eight transducers is considered, four ultrasonic transducers and four weight transducers, and if cost considerations require the choice of a smaller total number of transducers, it is a question of which of the eight transducers should be eliminated. Fortunately, the neural network technology provides a technique for determining which of the eight transducers is most important, which is next most important, etc. If the six most critical transducers are chosen, that is the six transducers which contain the most useful information as determined by the neural network, and a neural network can be trained using data from those six transducers and the overall accuracy of the system can be determined. Experience has determined, for example, that typically there is almost no loss in accuracy by eliminating two of the eight transducers, that is two of the strain gage weight sensors. A slight loss of accuracy occurs when one of the ultrasonic transducers is then eliminated.

This same technique can be used with the additional transducers described above. A transducer space can be determined with perhaps twenty different transducers comprised of ultrasonic, optical, electromagnetic, motion, heartbeat, weight, seat track, seatbelt payout, seatback angle etc. transducers. The neural network can then be used in conjunction with a cost function to determine the cost of system accuracy. In this manner, the optimum combination of any system cost and accuracy level can be determined.

In many situations where the four strain measuring weight sensors are applied to the vehicle seat structure, the distribution of the weight among the four strain gage sensors, for example, well very significantly depending on the position of the seat in the vehicle and particularly the fore and aft and secondarily the seatback angle position. A significant improvement to the accuracy of the strain gage weight sensors, particularly if less than four such sensors are used, can result by using information from a seat track position and/or a seatback angle sensor. In many vehicles, such sensors already exist and therefore the incorporation of this information results in little additional cost to the system and results in significant improvements in the accuracy of the weight sensors.

There have been attempts to use seat weight sensors to determine the load distribution of the occupying item and thereby reach a conclusion about the state of seat occupancy. For example, if a forward facing human is out of position, the weight distribution on the seat will be different than if the occupant is in position. Similarly a rear facing child seat will have a different weight distribution than a forward facing child seat. This information is useful for determining the seated state of the occupying item under static or slowly changing conditions. For example, even when the vehicle is traveling on moderately rough roads, a long term averaging or filtering technique can be used to determine the total weight and weight distribution of the occupying item. Thus, this information can be useful in differentiating between a forward facing and rear facing child seat.

It is much less useful however for the case of a forward facing human or forward facing child seat that becomes out of position during a crash. Panic braking prior to a crash, particularly on a rough road surface, will cause dramatic fluctuations in the output of the strain sensing elements. Filtering algorithms, which require a significant time slice of data, will also not be particularly useful. A neural network or other pattern recognition system, however, can be trained to recognize such situations and provide useful information to improve system accuracy.

Other dynamical techniques can also provide useful information especially if combined with data from the vehicle crash accelerometer. By studying the average weight over a few cycles, as measured by each transducer independently, a determination can be made that the weight distribution is

changing. Depending on the magnitude of the change a determination can be made as to whether the occupant is being restrained by a seatbelt. It a seatbelt restraint is not being used, the output from the crash accelerometer can be used to accurately project the position of the occupant during pre crash braking and eventually the impact itself providing his or her initial position is known.

In this manner, a weight sensor with provides weight distribution information can provide useful information to improve the accuracy of the occupant position sensing system for dynamic out of position determination. Naturally, even without the weight sensor information, the use of the vehicle crash sensor data in conjunction with any means of determining the belted state of the occupant will dramatically improve the dynamic determination of the position of a vehicle occupant.

Strain gage weight sensors can also be mounted in other locations such as within a cavity within a seat cushion **2** as shown as **6'** in FIG. **1**A and described above. The strain gage can be mounted on a flexible diaphragm that flexes and thereby strains the strain gage as the seat is loaded. In the example of FIG. **1**A, a single chamber **5'**, diaphragm and strain gage **6'** is illustrated. Naturally, a plurality of such chambers can be used to provide a distribution of the load on the occupying item onto the seat.

FIG. **23** shows a flow chart of one manner in the arrangement and method for controlling a vehicle component in accordance with the invention functions. A measurement of the morphology of the occupant **710** is performed at **714**, i.e., one or more morphological characteristics are measured in any of the ways described above. The position of the seat **716** is obtained at **718** and both the measured morphological characteristic of the occupant **712** and the position of the seat **716** are forwarded to the control system **720**. The control system considers these parameters and determines the manner in which the component **722** should be controlled or adjusted, and even whether any adjustment is necessary.

Preferably, seat adjustment means **724** are provided to enable automatic adjustment of the seat **716**. If so, the current position of the seat **716** is stored in memory means **726** (which may be a previously adjusted position) and additional seat adjustment, if any, is determined by the control system **720** to direct the seat adjustment means **724** to move the seat. The seat **716** may be moved alone, i.e., considered as the component, or adjusted together with another component, i.e., considered separate from the component (represented by way of the dotted line in FIG. **23**).

Although several preferred embodiments are illustrated and described above, there are other possible combinations using different sensors which measure either the same or different morphological characteristics, such as knee position, of an occupant to accomplish the same or similar goals as those described herein.

It should be mentioned that the adjustment system may be used in conjunction with each vehicle seat. In this case, if a seat is determined to be unoccupied, then the processor means may be designed to adjust the seat for the benefit of other occupants, i.e., if a front passenger side seat is unoccupied but the rear passenger side seat is occupied, then adjustment system might adjust the front seat for the benefit of the rear-seated passenger, e.g., move the seat base forward.

Disclosed above is a vehicle seat structure comprises a seat defining a surface adapted to contact an occupying item and a weight sensor arrangement arranged in connection with the seat for providing an indication of the weight applied by the occupying item to the surface of the seat. The weight sensor arrangement includes conductive members spaced apart from one another such that a capacitance develops between opposed ones of the conductive members upon incorporation of the conductive members in an electrical circuit. The capacitance is based on the space between the conductive members which varies in relation to the weight applied by the occupying item to the surface of the seat. The weight sensor arrangement may include a pair of non-metallic substrates and a layer of material situated between the non-metallic substrates, possibly a compressible material. The conductive members may comprise a first electrode arranged on a first side of the material layer and a second electrode arranged on a second side of the material layer. The weight sensor arrangement may be arranged in connection with slide mechanisms adapted to support the seat on a substrate of the vehicle while enabling movement of the seat, possibly between the slide mechanisms and the seat. If bolts attach the seat to the slide mechanisms, the conductive members may be annular and placed on the bolts.

Another embodiment of a seat structure comprises a seat defining a surface adapted to contact an occupying item, slide mechanisms adapted to support the seat on a substrate of the vehicle while enabling movement of the seat and a weight sensor arrangement interposed between the seat and the slide mechanisms for measuring displacement of the seat which provides an indication of the weight applied by the occupying item to the seat. The weight sensor arrangement can include a capacitance sensor which measures a capacitance which varies in relation to the displacement of the seat. The capacitance sensor can include conductive members spaced apart from one another such that a capacitance develops between opposed ones of the conductive members upon incorporation of the members in an electrical circuit, the capacitance being based on the space between the members which varies in relation to the weight applied by the occupying item to the seat.

The weight sensor arrangement can comprise a spring system arranged underneath a seat cushion and a sensor arranged in association with the spring system for generating a signal based on downward movement of the cushion caused by occupancy of the seat which is indicative of the weight of the occupying item. The sensor may be a displacement sensor structured and arranged to measure displacement of the spring system caused by occupancy of the seat. Such a sensor can comprise a spring retained at both ends and which is tensioned upon downward movement of the spring system and measuring means for measuring a force in the spring indicative of weight of the occupying item. The measuring means can comprise a strain gage for measuring strain of the spring or a force-measuring device.

The sensor may also comprise a support, a cable retained at one end by the support and a length-measuring device arranged at an opposite end of the cable for measuring elongation of the cable indicative of weight of the occupying item. The sensor can also comprises one or more SAW strain gages and/or structured and arranged to measure a physical state of the spring system.

In one weight measuring method in accordance with the invention disclosed above, at least one strain gage transducer is mounted at a respective location on the support structure and provides a measurement of the strain of the support structure at that location, and the weight of the occupying item of the seat is determined based on the strain of the support structure measured by the strain gage transducer(s). In another method, the seat includes the slide mechanisms for mounting the seat to a substrate and bolts for mounting the seat to the slide mechanisms, the pressure

exerted on the seat is measured by at least one pressure sensor arranged between one of the slide mechanisms and the seat. Each pressure sensor typically comprises first and second layers of shock absorbing material spaced from one another and a pressure sensitive material interposed between the first and second layers of shock absorbing material. The weight of the occupying item of the seat is determined based on the pressure measured by the at least one pressure sensor. In still another method for measuring the weight of an occupying item of a seat, a load cell is mounted between the seat and a substrate on which the seat is supported. The load cell includes a member and a strain gage arranged thereon to measure tensile strain therein caused by weight of an occupying item of the seat. The weight of the occupying item of the seat is determined based on the strain in the member measured by the strain gage. Naturally, the load cell can be incorporated at other locations in the seat support structure and need not be between the seat and substrate. In such a case, however, the seat would need to be especially designed for that particular mounting location. The seat would then become the weight measuring device.

Furthermore, although the weight measuring system and apparatus described above are described for particular use in a vehicle, it is of course possible to apply the same constructions to measure the weight of an occupying item on other seats in non-vehicular applications, if a weight measurement is desired for some purpose.

Thus, disclosed above are apparatus for measuring the weight of an occupying item of a seat including at least one strain gage transducer, each mounted at a respective location on a support structure of the seat and arranged to provide a measurement of the strain of the support structure thereat. A control system is coupled to the strain gage transducer(s) for determining the weight of the occupying item of the seat based on the strain of the support structure measured by the strain gage transducer(s). The support structure of the seat is mounted to a substrate such as a floor pan of a motor vehicle. Electrical connection means such as wires connect the strain gage transducer(s) to the control system. Each strain gage transducer may incorporate signal conditioning circuitry and an analog to digital converter such that the measured strain is output as a digital signal. The positioning of the strain gage transducer(s) depends in large part on the actual construction of the support structure of the seat. Thus, when the support structure comprises two elongate slide mechanisms adapted to be mounted on the substrate and support members for coupling the seat to the slide mechanisms, several strain gage transducers may be used, each arranged on a respective support member. If the support structure further includes a slide member, another strain gage transducer may be mounted thereon. Means for increasing the accuracy of the strain gage transducers and/or concentrating the strain caused by occupancy of the seat are advantageous and include, for example, forming a support member from first and second tubes having longitudinally opposed ends and a third tube overlying the opposed ends of the first and second tubes and connected to the first and second tubes whereby a strain gage transducer is arranged on the third tube. Naturally, other structural shapes may be used in place of one or more of the tubes.

Another disclosed embodiment of an apparatus for measuring the weight of an occupying item of a seat includes slide mechanisms for mounting the seat to a substrate and bolts for mounting the seat to the slide mechanisms, the apparatus comprises at least one pressure sensor arranged between one of the slide mechanisms and the seat for measuring pressure exerted on the seat. Each pressure sensor may comprise first and second layers of shock absorbing material spaced from one another and a pressure sensitive material interposed between the first and second layers of shock absorbing material. A control system is coupled to the pressure sensitive material for determining the weight of the occupying item of the seat based on the pressure measured by the at least one pressure sensor. The pressure sensitive material may include an electrode on upper and lower faces thereof.

Another disclosed embodiment of an apparatus for measuring the weight of an occupying item of a seat includes a load cell adapted to be mounted to the seat and to a substrate on which the seat is supported. The load cell includes a member and a strain gage arranged thereon to measure tensile strain in the member caused by weight of an occupying item of the seat. A control system is coupled to the strain gage for determining the weight of an occupying item of the seat based on the strain in the member measured by the strain gage. If the member is a beam and the strain gage includes two strain sensing elements, then one strain-sensing element is arranged in a longitudinal direction of the beam and the other is arranged in a transverse direction of the beam. If four strain sensing elements are present, a first pair is arranged in a longitudinal direction of the beam and a second pair is arranged in a transverse direction of the beam. The member may be a tube in which case, a strain-sensing element is arranged on the tube to measure compressive strain in the tube and another strain sensing element is arranged on the tube to measure tensile strain in the tube. The member may also be an elongate torsion bar mounted at its ends to the substrate. In this case, the load cell includes a lever arranged between the ends of the torsion bar and connected to the seat such that a torque is imparted to the torsion bar upon weight being exerted on the seat. The strain gage thus includes a torsional strain-sensing element.

Furthermore, disclosed herein is, a vehicle seat comprises a cushion defining a surface adapted to support an occupying item, a spring system arranged underneath the cushion and a sensor arranged in association with the spring system for generating a signal based on downward movement of the cushion and/or spring system caused by occupancy of the seat which is indicative of the weight of the occupying item. The spring system may be in contact with the sensor. The sensor may be a displacement sensor structured and arranged to measure displacement of the spring system caused by occupancy of the seat. In the alternative, the sensor may be designed to measure deflection of a bottom of the cushion, e.g., placed on the bottom of the cushion. Instead of a displacement sensor, the sensor can comprise a spring retained at both ends and which is tensioned upon downward movement of the spring system and measuring means for measuring a force in the spring indicative of weight of the occupying item. Non-limiting constructions of the measuring means include a strain gage for measuring strain of the spring or measuring means comprise a force measuring device. The sensor can also comprises a support, a cable retained at one end by the support and a length-measuring device arranged at an opposite end of the cable for measuring elongation of the cable indicative of weight of the occupying item. In this case, the length measuring device may comprises a cylinder, a rod arranged in the cylinder and connected to the opposite end of the cable, a spring arranged in the cylinder and connected to the rod to resist elongation of the cable and windings arranged in the cylinder. The amount of coupling between the windings provides an indication of the extent of elongation of the cable. A strain gage can also be used to measure the change in length of the

cable. In one particular embodiment, the sensor comprises one or more strain gages structured and arranged to measure a physical state of the spring system or the seat. Electrical connection means such as wires connect the strain gage(s) to the control system. Each strain gage transducer may incorporate signal conditioning circuitry and an analog to digital converter such that the measured strain is output as a digital signal. Alternately, a surface acoustical wave (SAW) strain gage can be used in place of conventional wire, foil or silicon strain gages and the strain measured either wirelessly or by a wire connection. For SAW strain gages, the electronic signal conditioning can be associated directly with the gage or remotely in an electronic control module as desired.

In a method for measuring weight of an occupying item on a seat fushion of a vehicle, a spring system is arranged underneath the cushion and a sensor is arranged in association with the cushion for generating a signal based on downward movement of the cushion and/or spring system caused by the occupying item which is indicative of the weight of the occupying item. The particular constructions of the spring system and sensor discussed above can be implemented in the method.

Another embodiment of a weight sensor system comprises a spring system adapted to be arranged underneath the cushion and extend between the supports and a sensor arranged in association with the spring system for generating a signal indicative of the weight applied to the cushion based on downward movement of the cushion and/or spring system caused by the weight applied to the seat. The particular constructions of the spring system and sensor discussed above can be implemented in this embodiment.

An embodiment of a vehicle including an arrangement for controlling a component based on an occupying item of the vehicle comprises a cushion defining a surface adapted to support the occupying item, a spring system arranged underneath the cushion, a sensor arranged in association with the spring system for generating a signal indicative of the weight of the occupying item based on downward movement of the cushion and/or spring system caused by occupancy of the seat and a processor coupled to the sensor for receiving the signal indicative of the weight of the occupying item and generating a control signal for controlling the component. The particular constructions of the spring system and sensor discussed above can be implemented in this embodiment. The component may be an airbag module or several airbag modules, or any other type of occupant protection or restraint device.

A method for controlling a component in a vehicle based on an occupying item comprises the steps of arranging a spring system arranged underneath a cushion on which the occupying item may rest, arranging a sensor in association with the cushion for generating a signal based on downward movement of the cushion and/or spring system caused by the occupying item which is indicative of the weight of the occupying item, and controlling the component based on the signal indicative of the weight of the occupying item. The particular constructions of the spring system and sensor discussed above can be implemented in this method.

Further, disclosed above is a vehicle seat structure which comprises a seat or cushion defining a surface adapted to contact an occupying item, slide mechanisms coupled to the seat for enabling movement of the seat, support members for supporting the seat on the slide mechanisms such that at least a portion of the weight of the occupying item passes through the support members. At least one of the support members has a region with a lower stiffness than a remaining region of the support member. The remaining regions of the support member are not necessarily the entire remaining portions of the support member and they may be multiple regions with a lower stiffness than other regions. A strain gage measurement system generates a signal indicative of the weight of the occupying item. The strain gage measurement system includes at least one strain gage transducer arranged in a lower stiffness region of the support member to measure strain thereof. The support member(s) may be tubular whereby the lower stiffness region has a smaller diameter than a diameter of the remaining region. If the support member is not tubular, the lower stiffness region may have a smaller circumference than a circumference of a remaining region of the support member. Each support member may have a first end connected to one of the slide mechanisms and a second end connected to the seat. Electrical connection means, such as wires or electromagnetic waves which transfer power wirelessly, connect the strain gage transducer(s) to the control system. Each strain gage transducer may incorporate signal conditioning circuitry and an analog to digital converter such that the measured strain is output as a digital signal. Alternately, a surface acoustical wave (SAW) strain gage can be used in place of conventional wire, foil or silicon strain gages and the strain transmitted either wirelessly or by a wire connection. For SAW strain gages, the electronic signal conditioning can be associated directly with the gage or remotely in an electronic control module as desired. The strain gage measurement system preferably includes at least one additional strain gage transducer arranged on another support member and a control system coupled to the strain gage transducers for receiving the strain measured by the strain gage transducers and providing the signal indicative of the weight of the occupying item.

In a method for measuring weight of an occupying item in a vehicle seat disclosed above, support members are interposed between the seat and slide mechanisms which enable movement of the seat and such that at least a portion of the weight of the occupying item passes through the support members, at least one of the support members is provided with a region having a lower stiffness than a remaining region, at least one strain gage transducer is arranged in the lower stiffness region of the support member to measure strain thereof and an indication of the weight of the occupying item is obtained based at least in part on the strain of the lower stiffness region of the support member measured by the strain gage transducer(s). The support member(s) may be formed by providing an elongate member and cutting around the circumference of the elongate member to thereby obtain the lower stiffness region or by other means.

A vehicular arrangement for controlling a component based on an occupying item of the vehicle disclosed herein comprises a seat defining a surface adapted to contact the occupying item, slide mechanisms coupled to the seat for enabling movement of the seat, support members for supporting the seat on the slide mechanisms such that at least a portion of the weight of the occupying item passes through the support members. At least one of the support members has a region with a lower stiffness than a remaining region of the support member. A strain gage measurement system generates a signal indicative of the weight of the occupying item, and a processor coupled to the strain gage measurement system receives the signal indicative of the weight of the occupying item and generates a control signal for controlling the component. The strain gage measurement system includes at least one strain gage transducer arranged in the lower stiffness region of the support member to measure strain thereof The component can be any vehicular

component, system or subsystem which can utilize the weight of the occupying item of the seat for control, e.g., an airbag system.

Another method for controlling a component in a vehicle based on an occupying item disclosed herein comprises the steps of interposing support members between a seat on which the occupying item may rest and slide mechanisms which enable movement of the seat and such that at least a portion of the weight of the occupying item passes through the support members, providing at least one of the support members with a region having a lower stiffness than a remaining region, arranging at least one strain gage transducer in the lower stiffness region of the support member to measure strain thereof, and controlling the component based at least in part on the strain of the lower stiffness region of the support member measured by the strain gage transducer (s). If the component is an airbag, the step of controlling the component can entail controlling the rate of deployment of the airbag, the start time of deployment, the inflation rate of the airbag, the rate of gas removal from the airbag and/or the maximum pressure in the airbag.

In another weight measuring system, one or more of the connecting members which connect the seat to the slide mechanisms comprises an elongate stud having first and second threaded end regions and an unthreaded intermediate region between the first and second threaded end regions, the first threaded end region engaging the seat and the second threaded end region engaging one of the slide mechanisms, and a strain gage measurement system arranged on the unthreaded intermediate region for measuring strain in the connecting member at the unthreaded intermediate region which is indicative of weight being applied by an occupying item in the seat. The strain gage measurement system may comprises a SAW strain gage and associated circuitry and electric components capable of receiving a wave and transmitting a wave modified by virtue of the strain in the connecting member, e.g., an antenna. The connecting member can be made of a non-metallic, composite material to avoid problems with the electromagnetic wave propagation. An interrogator may be provided for communicating wirelessly with the SAW strain gage measurement system.

The weight measuring apparatus described above may be used in apparatus and methods for adjusting a vehicle component, although other weight measuring apparatus may also be used in the vehicle component adjusting systems and methods described immediately below.

One embodiment of such an apparatus in accordance with invention includes a first measuring system for measuring a first morphological characteristic of the occupying item of the seat and a second measuring system for measuring a second morphological characteristic of the occupying item. Morphological characteristics include the weight of the occupying item, the height of the occupying item from the bottom portion of the seat and if the occupying item is a human, the arm length, head diameter and leg length. The apparatus also includes processor means for receiving the output of the first and second measuring systems and for processing the outputs to evaluate a seated-state based on the outputs. The measuring systems described herein, as well as any other conventional measuring systems, may be used in the invention to measure the morphological characteristics of the occupying item.

One preferred embodiment of an adjustment system in accordance with the invention includes a plurality of wave-receiving sensors for receiving waves from the seat and its contents, if any, and one or more weight sensors for detecting weight of an occupant in the seat or an absence of weight applied onto the seat indicative of a vacant seat. The weight sensing apparatus may include strain sensors mounted on or associated with the seat structure such that the strain measuring elements respond to the magnitude of the weight of the occupying item. The apparatus also includes processor means for receiving the output of the wave-receiving sensors and the weight sensor(s) and for processing the outputs to evaluate a seated-state based on the outputs. The processor means then adjusts a part of the component or the component in its entirety based at least on the evaluation of the seated-state of the seat. The wave-receiving sensors may be ultrasonic sensors, optical sensors or electromagnetic sensors. If the wave-receiving sensors are ultrasonic or optical sensors, then they may also include transmitter means for transmitting ultrasonic or optical waves toward the seat. If the component is a seat, the system includes power means for moving at least one portion of the seat relative to the passenger compartment and control means connected to the power means for controlling the power means to move the portion(s) of the seat. In this case, the processor means may direct the control means to affect the power means based at least in part on the evaluation of the seated-state of the seat. With respect to the direction or regulation of the control means by the processor means, this may take the form of a regulation signal to the control means that no seat adjustment is needed, e.g., if the seat is occupied by a bag of groceries or a child seat in a rear or forward-facing position as determined by the evaluation of the output from the ultrasonic or optical and weight sensors. On the other hand, if the processor means determines that the seat is occupied by an adult or child for which adjustment of the seat is beneficial or desired, then the processor means may direct the control means to affect the power means accordingly. For example, if a child is detected on the seat, the processor means may be designed to lower the headrest. In certain embodiments, the apparatus may include one or more sensors each of which measures a morphological characteristic of the occupying item of the seat, e.g., the height or weight of the occupying item, and the processor means are arranged to obtain the input from these sensors and adjust the component accordingly. Thus, once the processor means evaluates the occupancy of the seat and determines that the occupancy is by an adult or child, then the processor means may additionally use either the obtained weight measurement or conduct additional measurements of morphological characteristics of the adult or child occupant and adjust the component accordingly. The processor means may be a single microprocessor for performing all of the functions described above. In the alternative, one microprocessor may be used for evaluating the occupancy of the seat and another for adjusting the component. The processor means may comprise an evaluation circuit implemented in hardware as an electronic circuit or in software as a computer program. In certain embodiments, a correlation function or state between the output of the various sensors and the desired result (i.e., seat occupancy identification and categorization) is determined, e.g., by a neural network that may be implemented in hardware as a neural computer or in software as a computer program. The correlation function or state that is determined by employing this neural network may also be contained in a microcomputer. In this case, the microcomputer can be employed as an evaluation circuit. The word circuit herein will be used to mean both an electronic circuit and the functional equivalent implemented on a microcomputer using software. In enhanced embodiments, a heart beat sensor may be provided for detecting the heart beat of the occupant and generating an output representative thereof.

The processor means additionally receive this output and evaluate the seated-state of the seat based in part thereon. In addition to or instead of such a heart beat sensor, a capacitive sensor and/or a motion sensor may be provided. The capacitive sensor detects the presence of the occupant and generates an output representative of the presence of the occupant. The motion sensor detects movement of the occupant and generates an output representative thereof. These outputs are provided to the processor means for possible use in the evaluation of the seated-state of the seat.

The portion of the apparatus which includes the ultrasonic, optical or electromagnetic sensors, weight measuring means and processor means which evaluate the occupancy of the seat based on the measured weight of the seat and its contents and the returned waves from the ultrasonic, optical or electromagnetic sensors may be considered to constitute a seated-state detecting unit. The seated-state detecting unit may further comprise a seat track position-detecting sensor. This sensor determines the position of the seat on the seat track in the forward and aft direction. In this case, the evaluation circuit evaluates the seated-state, based on a correlation function obtain from outputs of the ultrasonic sensors, an output of the one or more weight sensors, and an output of the seat track position detecting sensor. With this structure, there is the advantage that the identification between the flat configuration of a detected surface in a state where a passenger is not sitting in the seat and the flat configuration of a detected surface which is detected when a seat is slid backwards by the amount of the thickness of a passenger, that is, of identification of whether a passenger seat is vacant or occupied by a passenger, can be reliably performed. Furthermore, the seated-state detecting unit may also comprise a reclining angle detecting sensor, and the evaluation circuit may also evaluate the seated-state based on a correlation function obtained from outputs of the ultrasonic, optical or electromagnetic sensors, an output of the weight sensor(s), and an output of the reclining angle detecting sensor. In this case, if the tilted angle information of the back portion of the seat is added as evaluation information for the seated-state, identification can be clearly performed between the flat configuration of a surface detected when a passenger is in a slightly slouching state and the configuration of a surface detected when the back portion of a seat is slightly tilted forward and similar difficult-to-discriminate cases. This embodiment may even be combined with the output from a seat track position-detecting sensor to further enhance the evaluation circuit. Moreover, the seated-state detecting unit may further comprise a comparison circuit for comparing the output of the weight sensor(s) with a reference value. In this case, the evaluation circuit identifies an adult and a child based on the reference value. Preferably, the seated-state detecting unit comprises: a plurality of ultrasonic, optical or electromagnetic sensors for transmitting ultrasonic or electromagnetic waves toward a seat and receiving reflected waves from the seat; one or more weight sensors for detecting weight of a passenger in the seat; a seat track position detecting sensor; a reclining angle detecting sensor; and a neural network to which outputs of the ultrasonic or electromagnetic sensors and the weight sensor(s), an output of the seat track position detecting sensor, and an output of the reclining angle detecting sensor are inputted and which evaluates several kinds of seated-states, based on a correlation function obtained from the outputs. The kinds of seated-states that can be evaluated and categorized by the neural network include the following categories, among others, (i) a normally seated passenger and a forward facing child seat, (ii) an abnormally seated passenger and a rear-facing child seat, and (iii) a vacant seat. The seated-state detecting unit may further comprise a comparison circuit for comparing the output of the weight sensor(s) with a reference value and a gate circuit to which the evaluation signal and a comparison signal from the comparison circuit are input. This gate circuit, which may be implemented in software or hardware, outputs signals which evaluates several kinds of seated-states. These kinds of seated-states can include a (i) normally seated passenger, (ii) a forward facing child seat, (iii) an abnormally seated passenger, (iv) a rear facing child seat, and (v) a vacant seat. With this arrangement, the identification between a normally seated passenger and a forward facing child seat, the identification between an abnormally seated passenger and a rear facing child seat, and the identification of a vacant seat can be more reliably performed. The outputs of the plurality of ultrasonic or electromagnetic sensors, the output of the weight sensor(s), the outputs of the seat track position detecting sensor, and the outputs of the reclining angle detecting sensor are inputted to the neural network or other pattern recognition circuit, and the neural network determines the correlation function, based on training thereof during a training phase. The correlation function is then typically implemented in or incorporated into a microcomputer. For the purposes herein, neural network will be used to include both a single neural network, a plurality of neural networks, and other similar pattern recognition circuits or algorithms and combinations thereof including the combination of neural networks and fuzzy logic systems such as neural-fuzzy systems. To provide the input from the ultrasonic or electromagnetic sensors to the neural network, it is preferable that an initial reflected wave portion and a last reflected wave portion are removed from each of the reflected waves of the ultrasonic or electromagnetic sensors and then the output data is processed. This is a form of range gating. With this arrangement, the portions of the reflected ultrasonic or electromagnetic wave that do not contain useful information are removed from the analysis and the presence and recognition of an object on the passenger seat can be more accurately performed. The neural network determines the correlation function by performing a weighting process, based on output data from the plurality of ultrasonic or electromagnetic sensors, output data from the weight sensor(s), output data from the seat track position detecting sensor if present, and/or on output data from the reclining angle detecting sensor if present. Additionally, in advanced systems, outputs from the heartbeat and occupant motion sensors may be included.

In a disclosed method for determining the occupancy of a seat in a passenger compartment of a vehicle in accordance with the invention, waves such as ultrasonic or electromagnetic waves are transmitted into the passenger compartment toward the seat, reflected waves from the passenger compartment are received by a component which then generates an output representative thereof, the weight applied onto the seat is measured and an output is generated representative thereof and then the seated-state of the seat is evaluated based on the outputs from the sensors and the weight measuring means. The evaluation the seated-state of the seat may be accomplished by generating a function correlating the outputs representative of the received reflected waves and the measured weight and the seated-state of the seat, and incorporating the correlation function into a microcomputer. In the alternative, it is possible to generate a function correlating the outputs representative of the received reflected waves and the measured weight and the seated-state of the seat in a neural network, and execute the function

using the outputs representative of the received reflected waves and the measured weight as input into the neural network. To enhance the seated-state determination, the position of a seat track of the seat is measured and an output representative thereof is generated, and then the seated-state of the seat is evaluated based on the outputs representative of the received reflected waves, the measured weight and the measured seat track position. In addition to or instead of measuring the seat track position, it is possible to measure the reclining angle of the seat, i.e., the angle between the seat portion and the back portion of the seat, and generate an output representative thereof, and then evaluate the seated-state of the seat based on the outputs representative of the received reflected waves, the measured weight and the measured reclining angle of the seat (and seat track position, if measured). Furthermore, the output representative of the measured weight may be compared with a reference value, and the occupying object of the seat identified, e.g., as an adult or a child, based on the comparison of the measured weight with the reference value.

In additional embodiments, the present invention involves the measurement of one or more morphological characteristics of a vehicle occupant and the use of these measurements to classify the occupant as to size and weight, and then to use this classification to position a vehicle component, such as the seat, to a near optimum position for that class of occupant. Additional information concerning occupant preferences can also be associated with the occupant class so that when a person belonging to that particular class occupies the vehicle, the preferences associated with that class are implemented. These preferences and associated component adjustments include the seat location after it has been manually adjusted away from the position chosen initially by the system, the mirror location, temperature, radio station, steering wheel and steering column positions, etc. The preferred morphological characteristics used are the occupant height from the vehicle seat and weight of the occupant. The height is determined by sensors, usually ultrasonic or electromagnetic, located in the headrest or another convenient location. The weight is determined by one of a variety of technologies that measure either pressure on or displacement of the vehicle seat or the force or strain in the seat supporting structure.

Also disclosed above is an arrangement for controlling a component in a vehicle in combination with the vehicle which comprises measurement apparatus for measuring at least one morphological characteristic of an occupant, a determination circuit or system for obtaining a current position of at least a part of a seat on which the occupant is situated, and a control unit coupled to the measurement apparatus and the determination system for controlling the component based on the measured morphological characteristic(s) of the occupant and the current position of the seat. The component may be an occupant restraint device such as an airbag whereby the control unit could control inflation and/or deflation of the airbag, e.g., the flow of gas into and/or out of the airbag, and/or the direction of deployment of the airbag. The component could also be a brake pedal, an acceleration pedal, a rear-view mirror, a side mirror and a steering wheel. The measurement apparatus might measure a plurality of morphological characteristics of the occupant, possibly including the height of the occupant by means of a height sensor arranged in the seat, and the weight of the occupant.

A seat adjustment system can be provided, e.g., motors or actuators connected to various portions of the seat, and a memory unit in which the current position of the seat is stored. The adjustment system is coupled to the memory unit such that an adjusted position of the seat is stored in the memory unit. A processor is coupled to the measurement apparatus for determining an adjusted position of the seat for the occupant based on the measured morphological characteristic(s). The adjustment system is coupled to the processor such that the processor directs the adjustment system to move the seat to the determined adjusted position of the seat. The determination system may comprise a circuit, assembly or system for determining a current position of a bottom portion of the seat and/or a current position of a back portion of the seat.

A method for controlling a component in a vehicle comprises the steps of measuring at least one morphological characteristic of an occupant, obtaining a current position of at least a part of a seat on which the occupant is situated, for example the bottom portion and/or the back portion, and controlling the component based on the measured morphological characteristic(s) of the occupant and the current position of the seat. The morphological characteristic could be the height of the occupant (measured from the top surface of the seat bottom), the weight of the occupant, etc.

An arrangement for controlling deployment of a component in a vehicle in combination with the vehicle in accordance with the invention comprises measurement apparatus for measuring at least one morphological characteristic of an occupant, a processor coupled to the measurement apparatus for determining a new seat position based on the morphological characteristic(s) of the occupant, an adjustment system for adjusting the seat to the new seat position and a control unit coupled to the measurement apparatus and processor for controlling the component based on the measured morphological characteristic(s) of the occupant and the new seat position. The component could be a deployable occupant restraint device whereby the deployment of the occupant restraint device is controlled by the control unit. The processor may comprise a control circuit or module and can be arranged to determine a new position of a bottom portion and/or back portion of the seat. The adjustment system may comprise one or more motors for moving the seat or a portion thereof.

Also in accordance with the invention, an occupant protection device control system comprises a vehicle seat provided for a vehicle occupant and movable relative to a chassis of the vehicle, at least one motor for moving the seat, a processor for controlling the motor(s) to move the seat, a memory unit for retaining an occupant pre-defined seat locations, a memory actuation unit for causing the processor to direct the motor(s) to move the seat to the occupant pre-defined seat location retained in the memory unit, measuring apparatus for measuring at least one morphological characteristic of the occupant, an automatic adjustment system coupled to the processor for positioning the seat based on the morphological characteristic(s) measured by the measuring apparatus (if and when a change in positioning is required), a manual adjustment system coupled to the processor manually operable for permitting movement of the seat and an actuatable occupant protection device for protecting the occupant. The processor is arranged to control actuation of the occupant protection device based on the position of the seat wherein location of the occupant relative to the occupant protection device is related to the position of the seat. This relationship can be determined by approximation and analysis, e.g., obtained during a training and programming stage. More particularly, the processor can be designed to suppress actuation of the occupant protection device when the position of the seat indicates that the

occupant is more likely than not to be out-of-position for the actuation of the occupant protection device. Other factors can be considered by the processor when determining actuation of the occupant protection device. When the occupant protection device is an airbag system including airbag and enabling a variable inflation and/or deflation of the airbag, the processor can be designed to determine the inflation and/or deflation of the airbag based on the location of the occupant in view of the relationship between the location of the occupant and the position of the seat, e.g., varying an amount of gas flowing into the airbag during inflation or providing an exit orifice or valve arranged in the airbag and varying the size of the exit orifice or valve. The airbag may have an adjustable deployment direction, in which case, the processor can be designed to determine the deployment direction of the airbag based on the location of the occupant in view of the relationship between the location of the occupant and the position of the seat.

Although several preferred embodiments are illustrated and described above, there are possible combinations using other geometries, sensors, materials and different dimensions for the components that perform the same functions. This invention is not limited to the above embodiments and should be determined by the following claims. For example, the weight measuring apparatus and methods described above could be used in conjunction with a seat position sensor to provide for an accurate determination of the identification and location of the occupying item of the seat. There are also numerous additional applications in addition to those described above. This invention is not limited to the above embodiments and should be determined by the following claims.

What is claimed is:

1. In an automotive vehicle, a method for determining a position of an occupant in a seat having a bottom portion on which the occupant sits and a back portion situated at an angle to the bottom portion, comprising:

arranging a bladder having at least one chamber in the bottom portion;

measuring the pressure in the at least one chamber; and

determining the position of the occupant based at least in part on the measured pressure.

2. The method of claim **1**, wherein the bladder comprises a plurality of chambers.

3. The method of claim **2**, further comprising arranging each of the chambers at a different location in the bottom portion of the seat.

4. The method of claim **1**, wherein the pressure measuring step comprises arranging at least one transducer in association with each of the at least one chamber.

5. A method for deploying an occupant protection device in an automotive vehicle to protect an occupant during a crash involving the vehicle, comprising:

determining the position of the occupant as claimed in claim **1**; and

deploying the occupant protection device based at least in part on the determined position of the occupant.

6. The method of claim **1**, wherein the bladder defines an interior and comprises a plurality of chambers all of which are arranged in the interior of the bladder, further comprising arranging each of the chambers at a different location in the bottom portion of the seat.

7. In an automotive vehicle, a method for determining a classification of an occupant in a seat having a bottom portion on which the occupant sits and a back portion situated at an angle to the bottom portion, comprising:

arranging a bladder having at least one chamber in the bottom portion;

measuring the pressure in the at least one chamber; and

determining the classification of the occupant based at least in part on the measured pressure.

8. The method of claim **7**, wherein the bladder comprises a plurality of chambers.

9. The method of claim **8**, further comprising arranging each of the chambers at a different location in the bottom portion of the seat.

10. The method of claim **7**, wherein the pressure measuring step comprises arranging at least one transducer in association with each of the at least one chamber.

11. A method for deploying an occupant protection device in an automotive vehicle to protect an occupant during a crash involving the vehicle, comprising:

determining the classification of the occupant as claimed in claim **7**; and

deploying the occupant protection device based in part on the determined classification of the occupant.

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