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(54) **Method and system to determine a physiological state of a sow**

(57) Method for determining a physiological state of a sow, comprising the steps of non-invasively surveying a current state of activity of said sow during at least one discrete time slice of a current day; comparing the state of activity with stored data relating to at least one corre-

sponding time slice of at least one day preceding the current day; and determining on the base of said comparison the physiological state of said sow. The surveyed state of activity includes the time period during which the sow is standing and the time period during which the sow is laying down.

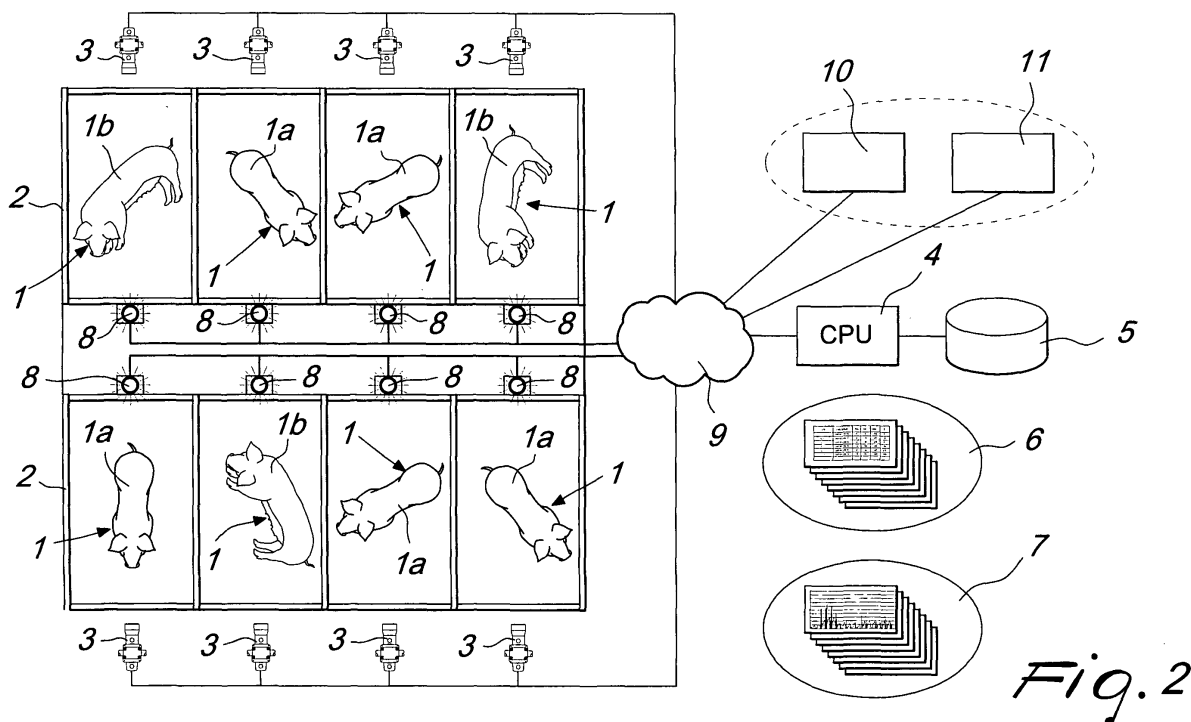


Fig. 2

Description

[0001] The present invention relates to a method for the determination of a physiological state of a sow and a system for operating this method. The invention is primarily intended to be used to determine whether a sow is on heat and, after the artificial insemination of a sow, to ascertain whether it is actually in state of pregnancy.

[0002] Field of application of the invention is primarily the pig breeding, which goal is to provide pigs that can subsequently be butchered to produce pork. The main factor of production in the pig breeding business is strictly related to the sow, which, in order to let it produce farrows, is normally artificially inseminated. The critical factor for succeeding in this operation is whether the insemination has been fulfilled in due time, since the sow can be made pregnant only during a small time window of 36 hours every about 20 days. For an efficient organisation of a pig breeding enterprise it is therefore indispensable to realise in time when the sow is on heat and hence ready for the artificial insemination.

[0003] The methods which are nowadays applied to solve this task, i.e. to find out the physiological state of a sow (on heat; not on heat) to determine whether it is ready for the artificial insemination, all utilise the interrelation between the physiological state of the sow (on heat; not on heat) and one of the following measurable or observable factors of the sow: degree of blood temperature, appearance of the pudenda, behaviour and agitation in presence of a boar.

[0004] A first method utilises the interrelation between the physiological state of the sow (on heat; not on heat) and its blood temperature and is based on the phenomenon that the sow's blood temperature slightly increases when it is on heat. The application of this method requires an at least daily measurement of the sow's blood temperature performed by adequate skilled personnel and a continuous observation and analysis of the actual measured values in order to realise in time a potential temperature rise which indicates that the sow is probably on heat and therefore ready for the artificial insemination.

[0005] A second method utilises the interrelation between the physiological state of the sow (on heat; not on heat) and the appearance of the sow's pudenda and is based on the phenomenon that in the case the sow is on heat its pudenda have a specific appearance. In order to detect in time a potential changing of the aspect of the sow's pudenda indicating that the sow is probably on heat and therefore ready for the artificial insemination, a day-today visual inspection of the sow's pudenda performed by adequate skilled personnel is necessary.

[0006] A third method utilises the interrelation between the physiological state of a sow (on heat, not on heat) and the influence on the sow's behaviour caused by the presence of a boar. If a sow is not on heat its behaviour is normally not affected by the presence of a boar, or in other words the sow behaves indifferently, regardless of whether a boar is present or absent.

[0007] However, in the case the same sow is on heat it behaves different in presence of a boar, in particular it is more agitated. In order to detect in due time whether a sow is on heat and therefore ready to be inseminated, a boar is daily skirted along the sows' cages and their reactions are observed by adequate skilled personnel. A particular agitation of a sow indicates that it is probably on heat and therefore ready for the artificial insemination.

[0008] As seen above all of the three common methods, which are nowadays applied to determine whether a sow is on heat and therefore ready for the artificial insemination, require at least one daily inspection of each single sow of the pig breeding by adequate skilled personnel, wherein the single operations are time-consuming and exhausting for the deployed staff, their application is complex and causes extensive expenses for a pig breeding.

[0009] Furthermore, the fact that the methods are manually performed by the staff not only requires much manpower for their application and makes them costly but also makes their result depend in large part on the "human factor", which - as is known - is affected by a degree of uncertainty. Therefore, the success of the known methods currently applied mainly depends on the staffs ability to detect that a sow is on heat in sufficient time to still have the possibility to perform the insemination during the small time window of about 36 hours, within which the sow can be made pregnant. In the case the staff fail to do so the sow will be inseminated at the wrong time and hence the result of the insemination will be negative. As a consequence thereof, the sow will not be productive for at least a following time period of about 20 days, while it continues to cause expenses for food, placement, care and reapplication of one of the methods to diagnose when the sow will be again on heat and the subsequent re-insemination.

[0010] Moreover, none of the known methods currently applied provides a methodical control of success in the artificial insemination upon termination thereof.

[0011] In fact, for subsequently checking if the sow has actually become pregnant, an echography is performed. This procedure requires adapted instruments, adequate skilled personnel and is quite time-consuming, so that its application is costly.

[0012] A first main aim of the present invention is to overcome the above mentioned problems of the above described methods currently applied by providing a more effective and more efficient method to determine when a sow is on heat in sufficient time to perform the artificial insemination before the small time window of about 36 hours during which the sow can be made pregnant ends.

[0013] Within this main aim, in order to achieve a superior efficiency, an object of the present invention is to reduce expenses, especially for the staff involved, by reducing the manpower requirement for the application of the method, especially by avoiding the need of operations that have to be manually performed by the staff and by avoiding devices to be brought in direct contact with the

sows.

[0014] Another object within the main aim of achieving a superior effectiveness is to increase the success rate expressed by the percentage of sows that - after their insemination - have actually become pregnant and the total amount of sows that have been inseminated or, in other words, to reduce the number of sows that are not pregnant although they have been inseminated.

[0015] A second main aim of the present invention in order to overcome the problems and deficiency of the known methods currently applied is to provide a method and a system to operate this method to verify soon after the artificial insemination if the sow is pregnant in order to implement an effective success control of the operation of the artificial insemination, avoiding also in this context the need of operations that have to be manually performed by the staff and devices that have to be brought in direct contact with the sows.

[0016] A further object is to provide a method which can be easily executed and a system to operate the method which can be easily used by the staff, in an automatic way so as to avoid application errors, which would negatively affect the business of pig breeding in terms of cost efficiency and which would therefore be anti-economic, as well as to avoid the need of specially skilled staff.

[0017] Furthermore, it is an object of the present invention to minimise the necessary adjustments for the conventionally run pig breeding when introducing the new method and the new system, so as to limit costs.

[0018] Finally, a further aim of the invention is to ease the operation of the method performed by the staff with respect to physical strain and time consumption.

[0019] These aims, these objects and others, which will become apparent hereinafter, are achieved by a method for determining a physiological state of a sow, comprising the steps of non-invasively surveying a current state of activity of said sow during at least one discrete time slice of a current day; comparing the state of activity with stored data relating to at least one corresponding time slice of at least one day preceding the current day; and determining on the base of said comparison the physiological state of said sow. The above aims and objects are also achieved by a system for determining a physiological state of a sow, comprising means for non-invasively surveying a current state of activity of said sow during at least one discrete time slice of a current day; means for comparing the state of activity with stored data relating to at least one corresponding time slice of at least one day preceding the current day; and means for determining on the base of said comparison the physiological state of said sow.

[0020] Further characteristics and advantages of the present invention will become apparent from the following detailed description, given by way of a non limitative example and illustrated in the accompanying figures, wherein:

elements of the system to run the methods shown in figures 3 and 4 for one single sow;

Figure 2 is an exemplary scheme showing the basic elements of the system to run the methods shown in figures 3 and 4 for a plurality of sows;

Figure 3 is a flow chart showing as basic principle the single steps of the method to determine whether a sow is on heat;

Figure 4 is a flow chart showing as basic principle the single steps of the method to determine whether a sow is pregnant;

Figure 5 shows an exemplary table in which the collected data regarding the activities of a single sow are recorded, organised and calculated; and

Figure 6 shows an exemplary graph with which the activities of one single sow are illustrated.

[0021] Figure 1 is a scheme showing the basic elements 1-8 of one possible and non-limitative embodiment of a system for running the methods shown in figures 3 and 4, limited to one single sow. Specifically, figure 1 discloses a device 3, which may be for instance a standard sensor or camera, adapted to reveal activities or movements (1a, 1b) of a single caged sow 1 placed in a sty 2 and which is connected to a central host 4. In the embodiment of figure 1 the sensing devices 3 are connected to the host 4, preferably through an RS485 line.

[0022] The host 4 can access a database 5 stored in a memory at or connected to the host. A signalling device 8, for example an alarm lamp, adapted to indicate a certain event is provided in the cage and is preferably connected to the sensing device 3.

[0023] In addition, figure 1 depicts a table 6, in which the collected data regarding the activities of one single caged sow 1 are recorded, organised and calculated and a graph 7, with which the measured activities of that single caged sow 1 are illustrated. The table 6 is obtained at the host 4 and serves for storing, calculating, organising the collected data regarding the activities of one sow 1 single caged in one of the eight boxes, while the graph 7 serves for displaying the measured activities of one sow 1 that is single caged in one of the eight boxes. The table and the graph will be discussed hereinafter with reference to figures 5 and 6.

[0024] Figure 2 is a scheme showing the elements of figure 1 in an arrangement comprising a plurality of single caged sows.

[0025] In detail, figure 2 discloses eight single caged sows 1 within a pigsty 2, which has accordingly eight single boxes arranged in two opposite lines along a small path for accessing these boxes and the sows therein. Each of the eight boxes is provided with the sensing device 3, like a sensor, camera or similar, adapted to register the activities of the single sow 1 placed therein, and the signalling device 8, adapted to indicate a certain state of the single sow 1.

[0026] A network 9 connects all of the devices 3 and 8 to the host 4. The host 4 comprises stored and installed

Figure 1 is an exemplary scheme showing the basic

therein the necessary software instructions for performing the method according to the invention, in particular the steps shown in figures 3 and 4. Moreover, the host 4 comprises stored and installed therein a communication application for interrogating and collecting data from the sensing devices 3. More preferably, the software installed in the host is based on DOTNET by MicrosoftTM and comprises a Webserver application, so as to provide remote client users 10 and 11, connected to the host via a communication network such as network 9, with web pages that can be accessed by using common browsers. [0027] Furthermore, in figure 2 a number of tables 6 and graphs 7 is shown.

[0028] Figure 3 is a flowchart showing the main steps 301-308 of the method used to automatically determine when a single caged sow 1 (see figures 1 and 2) is on heat and, therefore, is ready for the artificial insemination.

[0029] For applying this method, a sow is put, after its weaning, in a single box of a pigsty 2 and a so-called Sow Identification Number (SIN) 501 (see figure 5) is assigned to the sow 1 that has been single caged (step 301) in order to clearly identify the sow 1 in the further course of the method. The box is provided with the sensing device 3 for detecting the activities (i.e. the movements) of the sow 1 and, preferably, with the signalling device 8.

[0030] In a following step 302, data regarding the activities of the sow 1 is collected by the host 4 via the sensing device 3, during a plurality of consecutive predetermined time-slices of the current day.

[0031] In order to be able to automatically detect by means of the sensing device 3 how active the sow is during each preassigned time-slice, two different states 1a and 1b (see figures 1 and 2) of the sow 1 are defined which can be measured with the sensing device 3: a first state 1a is the sow 1 standing on its legs and a second state 1b is the sow 1 lying on the ground.

[0032] In detail, for the evaluation of the sow's activity state, key data are measured during the time slice, namely the total amount of time the sow has been standing on its legs (TUp 504, see figures 5 and 6), the total amount of time the sow has been lying on the ground of the box of the pigsty 2 (TDown 505, see figures 5 and 6).

[0033] Preferably, in order to picture how often the state 1a, 1b of the sow 1 has changed during the time slice of the current day, another key data is additionally or alternatively measured, which is the number of times the sow stands up (Times Up 503, see figures 5 and 6).

[0034] Then, in step 303, the results of step 302, i.e. the collected key data Times Up 503, TUp 504, TDown 505 are stored in the database, more precisely according to the table shown in figure 5. The three collected key data are contemporaneously assigned the SIN 501 of the sow 1 and a TIME STAMP 502, in order to clearly correlate the collected key data Times Up 503, TUp 504 and TDown 505 with the single caged sow 1 and the date and time of the day during which the key data were collected.

[0035] As is shown in figure 3, these steps 302 and 303 are repeated so long as a predefined time of the current day has been reached. Practically, this means that the key data Times Up 503, TUp 504 and TDown 505 for detecting the state of activity 1a, 1b of the sow 1 are separately collected by means of the sensing device 3 and subsequently separately stored in the table of the database 5 for preassigned time slices following one to another until a predefined time of day, for example eight o'clock in the morning, has been reached.

[0036] Upon reaching the predefined time of day, e.g. 8:00 a.m. (step 304), the following aggregate value (506) is calculated and stored for each cycle or time slice:

$$\sum_c (TUp_c / TDown_c) * T_{cycle}$$

where c is the time slice number within 24 hours, e.g. $c=1, 2, \dots, 144$ for a time slice of 10 minutes as in figure 5, and T_{cycle} is the duration of the time slice.

[0037] Then, the aggregate values 506 of the day are compared with the corresponding aggregate values relating to the same sow 1 which were collected in the previous days for analogous consecutive time slices, in order to determine whether the activity of the sow 1 significantly increased or changed.

[0038] A time filter is preferably applied for the period from midnight to 3:00 a.m.

[0039] Then, the percentage increase of each of the aggregate values is calculated according to the following formula:

$$\frac{\sum_{0:00-Ti,a}}{\sum_{0:00-Ti,n}} \times 100$$

where Σ is the aggregate value for the time slice Ti under consideration (from 3:00 a.m. on), a is the current day under consideration and n is one of the preceding days in which no "on heat" status was detected.

[0040] Considering the time filter from midnight to 3:00 a.m., the above percentage is calculated for each time slice preferably from 3:00 a.m. to 8:00 a.m., the increase being given by the duration of the time slice (e.g. 10 minutes), so as to take into account only the nocturnal activity of the sow.

[0041] Then, the 31 percentage increases obtained through the above formula are averaged so as to obtain a mean value $X_{a,n}$ for each day preceding the current day.

[0042] If each of the mean values $X_{a,n}$ does not exceed a predetermined value (step 305), preferably 80%, the sow is presumably not on heat. In other words, if the measured and calculated values based on the collected

key data of the time slices of the current day do not significantly overshoot the respective values of the collected data of the time slices of all the previous days in which no heat status was detected it is presumed that the sow shows a normal state of activity and consequently is not on heat.

[0043] In this case the host will continue to separately collect the key data Times Up 503, TUp 504 and TDown 505 with respect to the single caged sow 1 in the pigsty 2 for consecutive corresponding time slices until the same predefined time of the next day has been reached, after which a new comparison will be effected according to the foregoing algorithm.

[0044] If each of the mean values $X_{a,n}$ exceeds the predetermined value, preferably 80%, the sow is presumably on heat and a pre-alert situation is recognised to be preferably confirmed.

[0045] The confirmation is obtained through a similar algorithm, which is not based on the aggregate values 506 but is based on the Times up values 503. In this case, the "Times up" increase in percentage terms is as follows:

$$\frac{\#Up_{0:00-Ti,a}}{\#Up_{0:00-Ti,n}} \times 100$$

where $\#Up$ is the Times up value 503 for the time slice Ti under consideration (from 3:00 a.m. to 8:00 a.m.), a is the current day under consideration and n is one of the preceding days in which no "on heat" status was detected.

[0046] The 31 values so obtained are averaged so as to obtain a mean value $Y_{a,n}$ for each of the preceding days.

[0047] If each of the mean values $Y_{a,n}$ exceeds the predetermined value already identified, e.g. 80%, the pre-alert situation is confirmed and a corresponding alarm "SOW ON HEAT" (step 306) is triggered by means of the alarm device -8, to indicate that the sow 1 is on heat and therefore ready for the artificial insemination.

[0048] In alternative embodiments, the alarm "SOW ON HEAT" may also be triggered after checking the $X_{a,n}$ values only or by performing the check on the $Y_{a,n}$ values only.

[0049] In any case, after triggering the alarm "SOW ON HEAT" (step 306) the sow 1 is artificially inseminated in a conventional manner (step 307). As above, the step 307 of the artificial insemination must be performed as soon as possible after the indication that the sow is on heat, since the small time window within which the sow 1 can be made pregnant lasts only about 36 hours.

[0050] In a last step 308, whose single operations 308a-308e are shown in detail in figure 4 and described hereinafter, a check of the state of the sow 1 is preferably performed to verify whether the sow 1 that was artificially

inseminated has actually become pregnant.

[0051] If the result of the verification is positive, i.e. in case the sow has actually become pregnant, the so-called phase of pregnancy follows. Subsequently, after weaning a new production cycle begins and the above described method is applied again to the sow 1 which is newly single caged in one of the eight boxes of the pigsty 2.

[0052] If the verification of step 308 is negative, i.e. the sow 1 has not become pregnant, the sow 1 is immediately put again into one of the eight boxes of the pigsty 2 and the above specified method is applied again.

[0053] In figure 4 the single operations 308a-308e of step 308 of the method of figure 3 are shown in detail in form of a flowchart.

[0054] Specifically, after the artificial insemination of the sow 1, in a first step 308a data is collected with respect to the sow 1 for a certain span of time and separately for several consecutive time slices. In detail, the two key data TUp 504 and Tdown 505 are still measured.

[0055] These key data are registered in the database 5 and more precisely in the table shown in figure 5 while they are contemporaneously assigned the corresponding SIN and TIME STAMP for the same purpose already described above with regard to figure 3 (step 308b).

[0056] Subsequently, in operation 308c a graph as shown in figure 6 is created which shows along a time line 601 the percentage 603 indicating the total amount of time during which the sow 1 was standing on its legs TUp 504 and the total amount of time during which the sow 1 was lying on the ground of the box in the pigsty 2 TDown 505, separately for the several time slices.

[0057] In the same graph, only the amount of time 604 in which the sow was standing on its legs is shown, although expressed in thousandths of seconds.

[0058] In a following operation 308d the created graph is analysed and the result of this analysis lays the foundation for the conclusion whether the sow is in the state of pregnancy or less, as described below.

[0059] Should the curve 603 have a substantially Gaussian Distribution after having performed the artificial insemination, it is presumed that the sow has not become pregnant although it was inseminated and, accordingly, it is confirmed that the sow is not in the state of pregnancy (operation 308e').

[0060] Otherwise, if the curve 603 does not show a substantially Gaussian Distribution but has a truncated Gaussian aspect, it can be presumed that the sow has actually become pregnant and, accordingly, the algorithm 308 confirms that the sow 1 is in a state of pregnancy (operation 308e'').

[0061] Incidentally, it is noted that in certain zones of Figure 6 (between October 29 and October 31) there is a progressive increase in both the area and the peak value of curve 603, as well as in the height of peaks of curve 604. These trends denote that the sow on heat rises and stands on its feet in the night and at daybreak for a significant amount of time with respect to periods in

which it is not on heat.

[0062] It has thus been shown that the invention achieves the intended aim and objects. In particular, it has been shown that, by duly registering and analysing the nocturnal activity of the sow, it can be determined if it is on heat, without having to recur to boars or to invasive tests.

[0063] Clearly, several modifications to either the method and system according to the invention will be apparent to and can be readily made by the skilled in the art without departing from the scope of the present invention.

[0064] Therefore, the scope of the claims shall not be limited by the illustrations or the preferred embodiments given in the description in the form of examples, but rather the claims shall encompass all of the features of patentable novelty that reside in the present invention, including all the features that would be treated as equivalents by the skilled in the art.

[0065] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

Claims

1. Method for determining a physiological state of a sow, comprising the steps of:
 - non-invasively surveying a current state of activity of said sow during at least one discrete time slice of a current day;
 - comparing the state of activity with stored data relating to at least one corresponding time slice of at least one day preceding the current day;
 - determining on the base of said comparison the physiological state of said sow.
2. Method according to claim 1, wherein said physiological state comprises the state of heat of said sow.
3. Method according to claim 1 or 2, wherein said physiological state comprises the pregnancy of said sow.
4. Method according to one or more of the preceding claims, wherein said surveying the state of activity of said sow during said discrete time slice comprises surveying:
 - the time period during which the sow is standing and
 - the time period during which the sow is laying down.
5. Method according to one or more of the preceding claims, wherein said surveying the state of activity of said sow during said discrete time slice comprises surveying the number of times the sow rises to its legs.
6. Method according to one or more of the preceding claims, wherein the at least one previous day is a day in which the sow was determined as not being on heat.
7. Method according to one or more of the preceding claims, wherein said comparing comprises:
 - calculating for each time slice of the current day a percentage increase in the relationship between the time period during which the sow is standing and the time period during which the sow is laying down in the current day with respect to an analogous relationship in at least one of the preceding days;
 - comparing said percentage increase with a predetermined value,
 wherein said determining comprises determining whether said percentage increase exceeds said predetermined value.
8. Method according to claim 7, wherein said calculating is performed for each one of the preceding days and said percentage increase is averaged over the number of the preceding days, said determining comprising determining whether the averaged percentage increase exceeds said predetermined value.
9. Method according to at least one of the preceding claims, wherein said step of comparing further comprises the step of calculating a further percentage increase in the number of times the sow has risen to its legs during the current day with respect to the number of times the sow rose to its legs during at least one of the preceding days.
10. A system for determining a physiological state of a sow, comprising:
 - means for non-invasively surveying a current state of activity of said sow during at least one discrete time slice of a current day;
 - means for comparing the state of activity with stored data relating to at least one corresponding time slice of at least one day preceding the current day;
 - means for determining on the base of said comparison the physiological state of said sow.
11. The system according to claim 10, wherein said

physiological state is the state of heat of said sow.

12. The system according to claim 10, wherein said physiological state is the state of pregnancy of said sow. 5
13. System according to one or more of the claims 10-12, **characterised in that** said means for surveying the state of activity of said sow during said discrete time slice comprise means for surveying: 10
- the time period during which the sow is standing and
 - the time period during which the sow is laying down. 15
14. System according to one or more of claims 10-13, wherein said means for surveying the state of activity of said sow during said discrete time slice comprise means for surveying the number of times the sow rises to its legs. 20
15. System according to one or more of claims 10-14, wherein the at least one previous day is a day in which the sow was determined as not being on heat. 25
16. System according to one or more of claims 10-15, wherein said means for comparing are suitable to:
- calculate for each time slice of the current day a percentage increase in the ratio between the time period during which the sow is standing and the time period during which the sow is laying down in the current day with respect to an analogous relationship in at least one of the preceding days; 30
 - compare said percentage increase with a predetermined value, 35
- wherein said means for determining are suitable to determine whether said percentage increase exceeds said predetermined value. 40
17. System according to claim 16, wherein said means for comparing comprise instructions stored therein for performing said calculate step for each one of the preceding days and for averaging said percentage increase over the number of the preceding days, said means for determining being suitable to determine whether the averaged percentage increase exceeds said predetermined value. 45 50
18. System according to at least one of the preceding claims 10-17, wherein said means for comparing are suitable to calculate respective percentage increases in the number of times the sow has risen to its legs during the current day with respect to the number of times the sow rose to its legs during each 55

one of the preceding days and to average the calculated rise percentage increases over the number of the preceding days, said means for determining being suitable to determine whether said averaged rise percentage increase exceeds a predetermined value.

19. System according to one of more of claims 10-18, wherein said means for non-invasively surveying comprise a sensing device for detecting the stand up and lay down movements of a respective sow.
20. System according to claim 19, wherein said means for comparing and said means for determining are a host computer, which is connected to the sensing device.
21. System according to claim 20, wherein said host is connected to a plurality of sensing devices via a communication network and is preferably suitable to be accessed by a remote client.

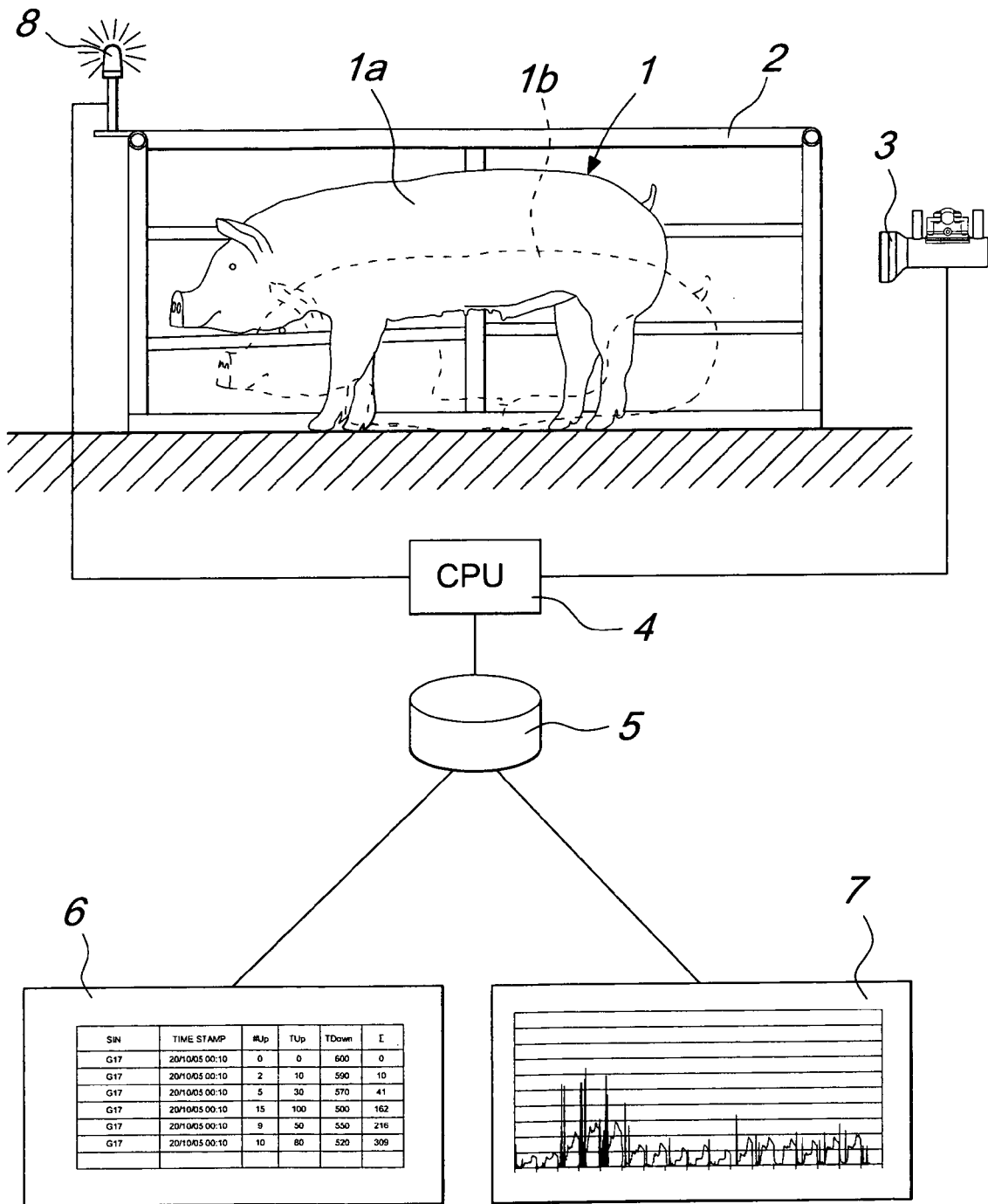


Fig. 1

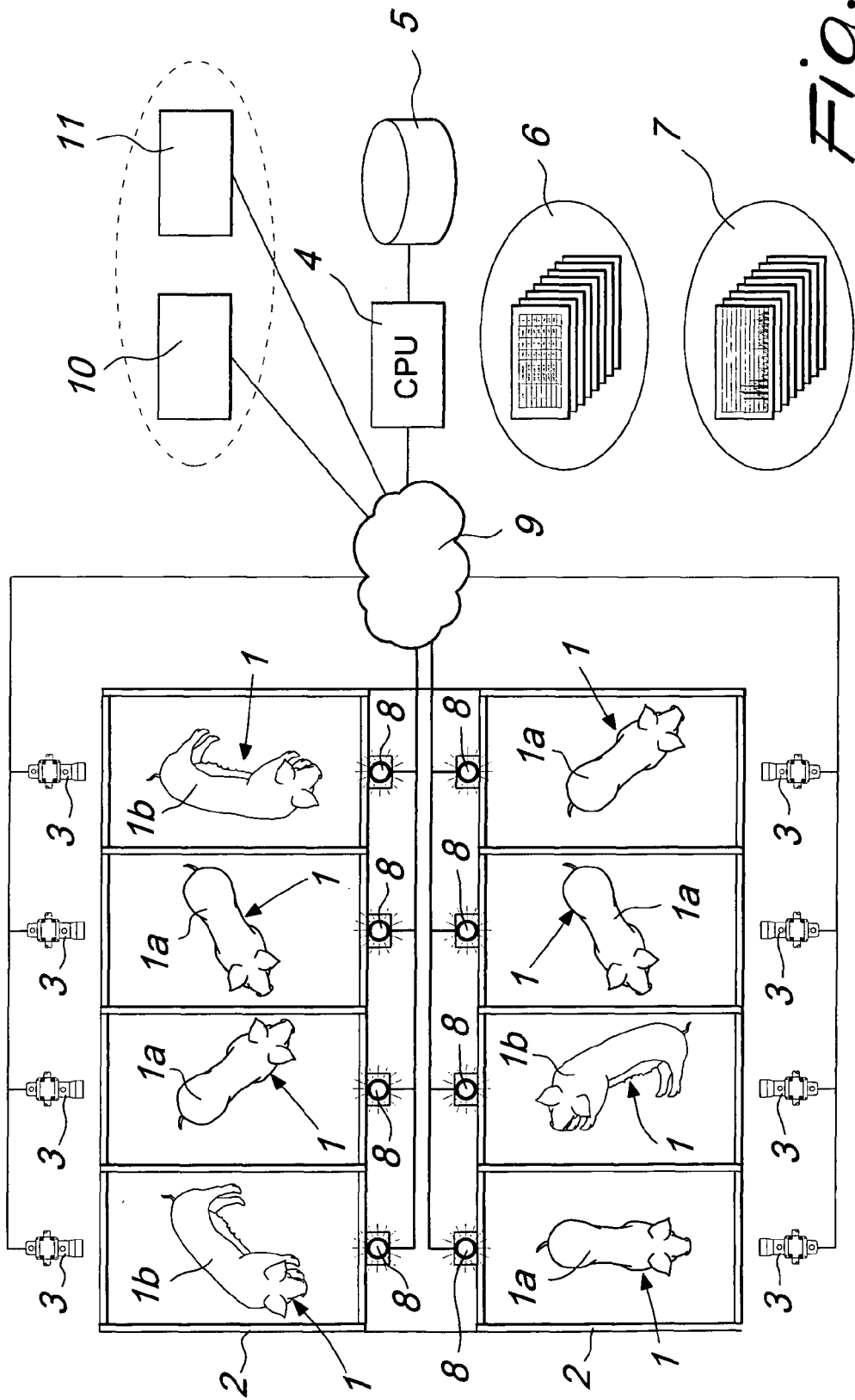
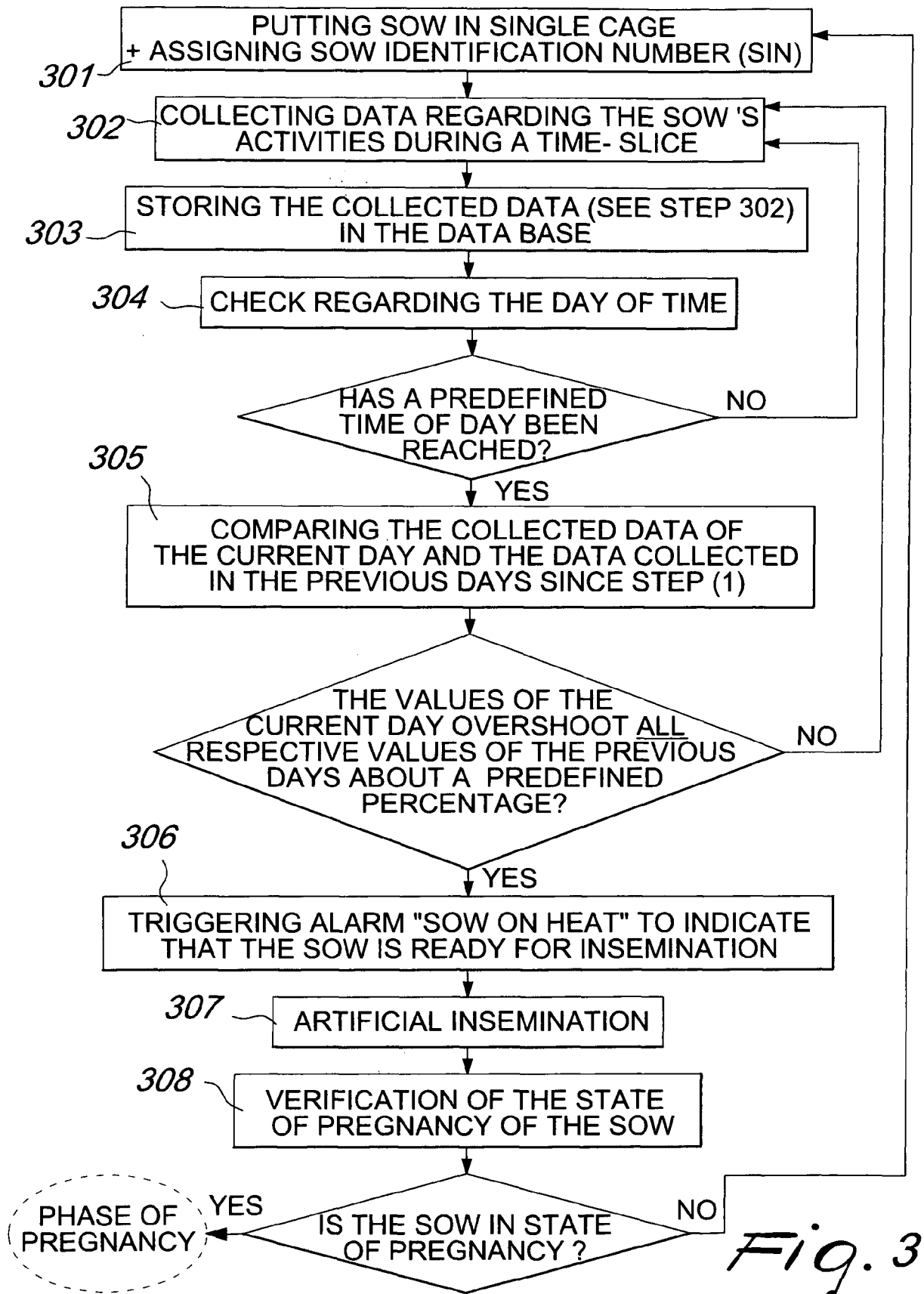
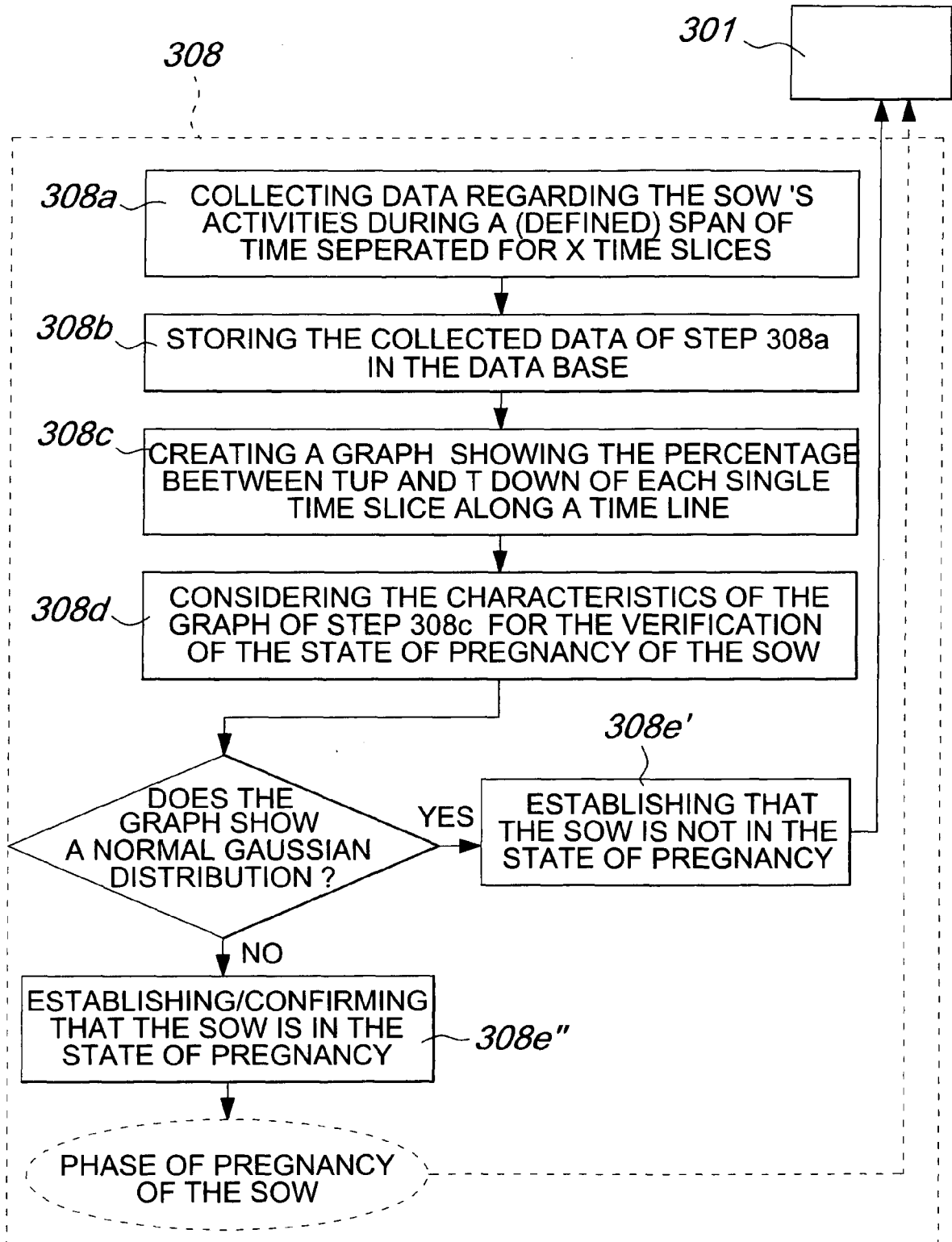
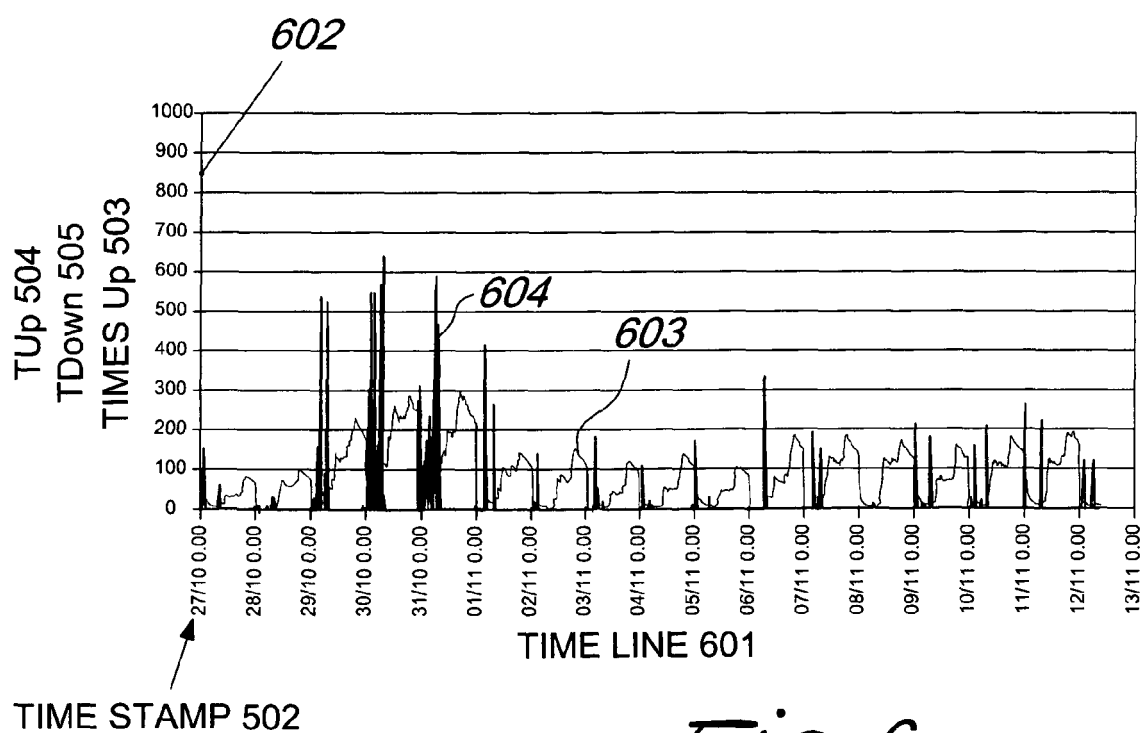


Fig. 2



*Fig. 4*

501 SIN	502 TIME STAMP	503 #Up	504 TUp	505 TDown	506 Σ
G17	20/10/05 00:10	0	0	600	0
G17	20/10/05 00:20	2	10	590	10
G17	20/10/05 00:30	5	30	570	41
G17	20/10/05 00:40	15	100	500	162
G17	20/10/05 00:50	9	50	550	216
G17	20/10/05 01:00	10	80	520	309

Fig. 5*Fig. 6*



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 00 6972

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 455 610 A (RODRIAN ET AL) 19 June 1984 (1984-06-19) * column 1, lines 27-37, 57-60 * * column 1, line 65 - column 2, line 3 * * column 2, lines 35-41 * * claim 1 *	1-11	INV. A61D17/00
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