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(54) **COMBINING MEASUREMENTS FROM DIFFERENT SENSORS**

KOMBINIEREN VON MESSUNGEN VON UNTERSCHIEDLICHEN SENSOREN

COMBINAISON DE MESURES PROVENANT DE DIFFERENTS CAPTEURS

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(56) References cited:
WO-A-00/27281 **WO-A-94/23495**
US-A- 4 949 710 **US-A- 5 626 140**
US-A- 5 853 364

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Description

[0001] The present invention relates to a method and apparatus for combining measurements from different sensors in order to provide an improved measurement of a parameter. It is particularly applicable to the measurement of physiological parameters.

[0002] Certain parameters can be measured in more than one way. This is useful in giving independent measures of the same quantity. For instance, in the medical field the heart rate can be measured both from an electrocardiogram (ECG) and from a pulse oximetry waveform (used to calculate oxygen saturation). In the accompanying drawings Figure 4 illustrates schematically these two waveforms, Figure 4a being the electrocardiogram with the heart rate illustrated as HR_1, and Figure 4b the pulse oximetry waveform with the heart rate illustrated as HR_2. The heart rate is a parameter which can undergo sudden changes. Some of these changes are valid physiological changes, for example ectopic beats which occur prematurely, and therefore give rise to a temporary increase in the heart rate. Figure 5 illustrates the occurrence of an ectopic beat 50 found in both the electrocardiogram trace and the pulse oximetry waveform. The shorter interval between the preceeding beat and the ectopic beat 50 manifests itself in a measurement of the heart rate as a sudden increase in the heart rate. Figures 1 and 2 of the accompanying drawings show time plots of the heart rate measured by pulse oximetry (Figure 1) and ECG (Figure 2). It can be seen that in Figures 1 and 2 the heart rate in the early part of the plot is generally of the order of 80bpm, but that there are occasional sudden increases in heart rate, such as indicated at 10 and 20 which are caused by ectopic beats and thus appear both in the measurement by pulse oximetry and the measurement by ECG.

[0003] However, in addition to changes in the measured heart rate deriving from valid physiological changes, other changes occur which are not physiologically valid, for instance being caused by sudden movement of the sensors on the body surface (e.g. chest movement with ECG electrodes). Figure 6 illustrates the presence of artefacts 60 on the pulse oximetry waveform which shorten the interval between apparent beats and thus result in apparent increases in the heart rate. These changes are reflected in one measurement, but not the other, as indicated at 12 and 22 in Figures 1 and 2 respectively. The fact that the changes appear in one measurement but not the other means that the two measurements could be combined to help decide which heart rate changes are valid physiological ones, and which are artefacts. However, the normal approach of validating one measurement channel against the other involving cross-correlation of the two measurements invariably fails because it is not possible to know in advance (for each recording, for each patient) what value to give to the threshold for accepting, rather than rejecting a change in the heart rate as being valid. Thus although it would appear from Figures 1 and 2 that a threshold could be set which would eliminate changes such as indicated as 22, such a threshold is not appropriate for all patients for all recordings, and does not help with the pulse oximetry waveform. The problems are increased in the event of atrial fibrillation when the heart rate changes rapidly as indicated in the region AF in Figures 1, 2 and 3.

[0004] Similar problems arise in other fields where a parameter is measured via two or more measurement channels.

[0005] US-A-5,626,140 discloses a method of fusing independent measurements of physiological parameters in accordance with the pre-characterizing portion of claim 1.

[0006] The present invention provides a method and apparatus for improving measurement of a parameter by combining two measurements of it in a way which allows valid changes to be distinguished from artefacts. Accordingly it provides a method of measuring a parameter as defined is claim 1.

[0007] Thus with the present invention a prediction is made for each measurement and the actual measurement is compared with its prediction. The difference is computed, which is termed the "innovation", and this innovation is used to calculate a weight which will be given to that measurement when it is combined with the other measurement, also weighted according to its innovation. The weights are calculated so that if the innovation on one measurement channel is high, whereas the innovation on the other measurement channel is low, the measurement from the low innovation channel is more heavily weighted. This is because a high level of innovation from one channel coinciding with a low innovation on the other channel is regarded as indicative of an artefact on the higher innovation channel. Thus, the weight given to each value when the values are combined is inversely related to the square or modulus of the difference between the measured value and its predicted value.

[0008] In one embodiment the measured values can be combined according to the formula:-

$$M = M_1 \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} + M_2 \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2} \qquad (1)$$

where M_1 and M_2 are the two measured values, and σ_1 and σ_2 are the differences between the two measured values and their respective predicted values.

[0009] The steps of prediction, measurement, calculation and combination are preferably repeated continuously, with the predicted value for each of the measurements being based on a linear predictive model, e.g the predicted value is based on its preceding predicted value and the preceding innovation (i.e. the difference between the preceding predicted value and the preceding measurement). The predicted value can be obtained by adding to the preceding predicted value a constant times the innovation. The constant is preferably a positive value less than or equal to unity. Alternatively the predicted value for each of the two independent measurements can be calculated by using a non-linear predictive model such as a neural network.

[0010] In one embodiment the predicted values can be based on a mathematical model of the system, which may include estimates for process noise and sensor (measurement) noise. Two independent models may be used, one for each of the measurement channels, and the models can include estimates for the process noise and sensor noise, which can be the same for the two channels. In one embodiment the models are Kalman filters.

[0011] The method is particularly applicable to the measurement of heart rate, in which case the two measurement channels can be from an electrocardiogram and a pulse oximetry waveform, though it is applicable to any other measurement of a . parameter which can be derived from two or more sources. Thus the method is applicable for more than two measurement channels, and both where the measurements are independent and where they are not truly independent such as from multiple leads of an ECG.

[0012] The invention can also provide for detection of movement artefacts. In this instance high values of innovation are obtained on both channels for the period of movement, and this can be used as a trigger to discard the sections of data which are corrupted by that movement.

[0013] It will be appreciated that the invention can be embodied using computer software and thus the invention extends to a computer program for controlling and executing the method or parts of it, and to a computer readable storage medium carrying the program. The invention also extends to corresponding apparatus for carrying out the method.

[0014] The invention will be further described by way of non-limitative example with reference to the accompanying drawings in which:-

Figure 1 illustrates a plot of heart rate measured by pulse oximetry;
Figure 2 illustrates a plot of heart rate measured by an ECG;
Figure 3 illustrates the result of combining the two plots of Figures 1 and.2 according to an embodiment of the invention;
Figure 4 illustrates schematically heart beats on an ECG and pulse oximetry waveform;
Figure 5 illustrates schematically ectopic beats appearing on an ECG and pulse oximetry waveform;
Figure 6 illustrates an ECG trace and pulse oximetry waveform with artefacts on the pulse oximetry waveform;
Figure 7 illustrates a plot of heart rate measured by an ECG;
Figure 8 illustrates predicted values for the heart rate according to one embodiment of the invention;
Figure 9 illustrates the innovation obtained from Figures 7 and 8;
Figure 10 illustrates the variance obtained from Figures 7 and 8.

[0015] An embodiment of the invention will now be described in which the invention is applied in the medical field to the measurement of heart rate using ECG and pulse oximetry. As illustrated in Figure 4a the heart rate measured by ECG is derived from the interval between two successive R-wave peaks. The heart rate measurement derived from the pulse oximetry waveform is obtained from the interval between two successive peaks (or troughs) as illustrated in Figure 4b. Figures 1 and 2 illustrate heart rate plots derived from these two measurements.

[0016] With this embodiment of the present invention a model of the process generating the heart rate is constructed. The same model is run independently for each measurement source (i.e. one for the ECG measurement channel and one for the pulse oximetry measurement channel). In this embodiment the model is a Kalman filter. In general a Kalman filter uses a process model and an observation model. The process model models the state of the system at time t+1 in terms of its state at time t. The measurement or observation model indicates how the measurement at time t is related to the state of the system at time t. Thus in general terms:-

$$\mathbf{x}_{t+1} = \mathbf{A}\mathbf{x}_t + \mathbf{w} \text{ (Process model)}$$

$$\mathbf{y}_t = \mathbf{C}\mathbf{x}_t + \mathbf{v} \text{ (Observation model)}$$

where:

$\mathbf{w} \sim \boldsymbol{N}(\mathbf{O}, \mathbf{Q})$ - Gaussian process noise with zero mean and variance $\mathbf{Q}$

v ~ ***N*** (**O, R**) - Gaussian measurement noise with zero mean and variance **R**

and:

- *k* - vector of state variables **x**
- *n* - vector of observable or measurements **y**
- State **x** evolves according to simple first-order Markov dynamics;
- **A** is the *k* x *k* state transition matrix
- Each measurement vector **y** is related to the current state by a linear observation process; **C** is the *n* x *k* observation or measurement matrix

[0017] In this embodiment the general Kalman filter is simplified to use scalar quantities and the same process and measurement noise models (*w*, *v*) are used on both measurement channel. Thus the simplified Kalman filter is as follows:-

$$x_{t+1} = \mathrm{A}x_t + w \quad \text{(Process model)}$$

$$y_t = \mathrm{C}x_t + v \quad \text{(Observation model)}$$

[0018] The model is further simplified by setting C=1, implying that the heart rate is both the state describing the process and the measurement. Further, it is assumed that A = 1, implying that the next heart rate is the same as the previous one with the variability allowed for by the process noise model.

[0019] Using this model, on each channel, the process of combining the two measurements then involves the following steps:-

1. From knowledge of previous history up to time t

   (a) predict the next state *xpred*;
   (b) from *xpred* predict the next measurement *ypred*

2. Make the measurement y_{t+1}
3. Compute the innovation:

$$y_{t+1} = ypred + \varepsilon_{t+1}$$

where ε_{t+1} is the difference between the actual value and the predicted value: the *innovation.*
4. Compute the variance σ_{t+1}^2:

$$\sigma_{t+1}^2 = \varepsilon_{t+1}^2$$

σ^2 the variance, is the inverse of the "confidence" which is associated with the prediction
5. Mix the heart rate measurements in inverse proportion to the variance associated with each one:

$$HR = HR_1 \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} + HR_2 \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2}$$

[0020] An example of an implementation of this model in MATLAB is given in Appendix 1. That example is general, and will work for vector quantities, though in this embodiment the quantities are scalar. It can be seen from appendix 1 that the predicted heart rate for each new measurement cycle (xnew) is equal to the previously predicted value (xpred) plus the Kalman gain K times the innovation e. The Kalman gain K is derived from the predicted variance Vpred and the measurement variance R. The predicted variance is derived from the previous predicted variance and the process noise

Q. To start the process off it is initialized using an initial value of the heart rate as 80 and an initial value of the state variance of 100. The process noise in the Q in this embodiment is set to 5 and the measurement noise variance R is set to 10.

[0021] It will be clear from the implementation that, as normal with a Kalman filter, the variance and Kalman gain are not dependent on the measurement values. The measurement values are only used in the new prediction of heart rate via the innovation e. Thus it will be noted that for the constant values of Q and R used in this example the Kalman gain K tends to 0.5 and the state co-variance V tends to 5. However, K can be made adaptive by modifying the values for the variance constants Q and R, preferably the process variance Q, according to the type of process being encountered, for example atrial fibrillation (where there is a high level of process noise) as opposed to a healthy heart rate (during which there is a low level of process noise).

[0022] Figures 8, 9 and 10 illustrate values for the estimated heart rate xpred, the innovation e and the variance σ^2 for the heart rate plot shown in Figure 7 (in this case the ECG measurement channel).

[0023] Figure 3 illustrates the result of combining the two measurement plots from Figures 1 and 2 using this embodiment. It can be seen that the movement artefacts 22 on the ECG channel in Figure 2 have been removed from the combined measurement, even though they occur during a period of atrial fibrillation.

[0024] Thus with this embodiment the difference between the measurement and its predicted value is used to indicated the degree of confidence in that measurement. The higher the difference the lower the confidence. Formula (1) above is used to combine the two measurements. This can be summarised as follows:

1) Valid heart rates on both channels: low innovation on both channels; weight both measurements equally
2) Valid sudden change (e.g. ectopic beat) seen on both channels: high innovation but on *both* channels; therefore, measurements are again weighted equally
3) Artefact on one channel: high innovation on one channel only; therefore the information from that channel is ignored by being given a very low weighting (low confidence).

[0025] The method can also be used to provide a movement artefact detector, i.e. to detect when movement artefact is present on both channels and therefore no useful information is available. This is characterised by high values of innovation on both channels for a sustained period of time. This can be used to discard the sections of raw data which are corrupted by this movement and to indicate that no valid heart rate estimate can be derived during those periods.

Appendix 1

[0026]

```
load -ascii ecghr_13
data_file = ecghr_13;
time = data_file (:,1);
hr = data_file (:,2);
start = 1
stop = size (data_file),1);
fprintf ('number of R-R intervals detected = %d \n', stop);
hr_limit = 200;
      % X(t+1) = A X(t)+noise(Q) - process model with Q as variance of noise w
      % Y(t) = C X(t)+noise(R) - measurement model with R as variance of noise v
      ss = 1; % state size - sets to one dimensional, ie scalar though routine works for vectors
      os = 1; % observation size - sets to one dimensional, ie scalar
      A = [1]; % assume x(t+1)=x(t)
      C = [1]; % assume y=x
      Q = 5.0*eye(ss); % process noise - eye is the identity matrix in MATLAB -here just unity
      R = 10.0*eye(os); % measurement noise variance
      initx = [80]; % initial state value (HR of 80 bpm)
      ini tV = 100*eye(ss); % initial state variance
      xnew = initx; % - initialisation
      Vnew = initV;
      for i = start: stop % - start of cycle
x = xnew; % update from previous cycle
V = Vnew; % update from previous cycle
xpred = A*x; % prediction of state
Vpred = A*V*A' + Q; % prediction of state covariance, A' is transpose of A
ypred (i) = C*xpred; % prediction of measurement
```

```
y(i) = hr(i); % "make measurement"
e = y(i) - ypred (i); % calculate innovation
innov(i) = e; % for plotting
sigma2 (i) - e*e; % variance for saving
S = C*Vpred*C’ + R; % innovation covariance
Sinv = inv (S); % invert S
K = Vpred*C’ *Sinv; % compute Kalman gain
xnew = xpred + K*e; % update state by the innovation controlled by the Kalman gain
Vnew = (eye (ss) - K*C) *Vpred; % update state covariance
end
end
```

Claims

1. A computer-implemented method of measuring a parameter comprising the steps of:

   predicting the value of the parameter,
   making two independent measurements of the parameter via respective ones of two independent measurement channels to produce two measured values of the parameter, and
   obtaining a new predicted value of the parameter based on the measurements;

   characterised in that:

   the step of predicting the new value of the parameter comprises predicting the value of each of the two independent measurements of the parameter for the two independent measurement channels by using a predictive model,

   and by the steps of:

   calculating the respective differences between the respective predicted values and measured values for each of said two independent measurement channels, and
   combining the two measured values weighted with weights determined by said differences.

2. A method according to claim 1 in which the steps of prediction, measurement, calculation and combination are repeated continuously, the predicted value for each of the two independent measurements being based on the preceding predicted value and the difference between the preceding predicted value and the preceding measurement.

3. A method according to claim 2 in which the predicted value for each of the two independent measurements is calculated by using a linear predictive model for each of said two independent measurement channels.

4. A method according to claim 2 in which the predicted value for each of the two independent measurements is calculated by using a non-linear predictive model for each of said two independent measurement channels.

5. A method according to claim 3 or 4 in which each model is adaptive, and it adapts in dependence upon the amount of process noise in the respective measurement channels.

6. A method according to any one of the preceding claims in which in the step of combining the two measured values the weight of each value varies inversely with the square of the difference between the predicted value and the measurement for that measurement channel.

7. A method according to claim 6 in which the two measured values are combined according to the formula:-

$$M = M_1 \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} + M_2 \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2}$$

where M_1 and M_2 are the two measured values, and σ_1 and σ_2 are the differences between the two measured values and their respective predicted values.

8. A method according to any one of the preceding claims in which the predicted values for the respective measurements are based on respective models for measurement of said parameter via said two independent measurement channels.

9. A method according to claim 8 in which the models include estimates for process noise and sensor noise for each of said two independent measurement channels.

10. A method according to claim 8 or 9 in which the respective models are mutually independent.

11. A method according to claim 10 in which the respective models include the same estimates for process noise and sensor noise.

12. A method according to claim 8, 9, 10, or 11 in which the respective models are Kalman filters.

13. A method according to any one of the preceding claims further comprising the step of discarding series of measurements for which the differences between both measured values and their predicted values exceed a predetermined threshold for a predetermined period of time.

14. A method according to any one of the preceding claims in which the parameter is the heart rate.

15. A method according to claim 14 in which the two independent measurements are made from an electrocardiograph and a pulse oximetry waveform respectively constituting said two independent measurement channels.

16. A method according to any one of the preceding claims in which there are more than two measurements.

17. A computer program comprising program code means for executing the method of any one of the preceding claims.

18. Apparatus comprising parameter measurement means and computing means, the apparatus being constructed and arranged to execute the method of any one of claims 1 to 16.

Patentansprüche

1. Computerimplementiertes Verfahren des Messens eines Parameters, umfassend die folgenden Schritte:

Prognostizieren des Werts des Parameters,
Erstellen zweier unabhängiger Messungen des Parameters über die entsprechenden der zwei unabhängigen Messkanäle zum Generieren zweier gemessener Werte des Parameters und
Erhalten eines neuen prognostizierten Werts des Parameters beruhend auf den Messungen; **dadurch gekennzeichnet, dass**:

der Schritt des Prognostizierens des neuen Werts des Parameters das Prognostizieren des Werts jeder der beiden unabhängigen Messungen des Parameters für die beiden unabhängigen Messkanäle durch die Verwendung eines Vorhersagemodells umfasst,

und durch die folgenden Schritte:

Berechnen der jeweiligen Unterschiede zwischen den jeweiligen prognostizierten Werten und gemessenen Werten für jeden der beiden unabhängigen Messkanäle und
Kombinieren der beiden gemessenen Werte unter Gewichtung mit Gewichten, die durch die Unterschiede festgelegt werden.

2. Verfahren nach Anspruch 1, bei dem die Schritte des Prognostizierens, der Messung, des Berechnens und der Kombination fortlaufend wiederholt werden, wobei der prognostizierte Wert für jede der beiden unabhängigen Messungen auf dem vorhergehenden prognostizierten Wert und dem Unterschied zwischen dem vorhergehenden prognostizierten Wert und der vorhergehenden Messung beruht.

3. Verfahren nach Anspruch 2, bei dem der prognostizierte Wert für jede der beiden unabhängigen Messungen durch die Verwendung eines linearen Vorhersagemodells für jeden der beiden unabhängigen Messkanäle berechnet wird.

4. Verfahren nach Anspruch 2, bei dem der prognostizierte Wert für jede der beiden unabhängigen Messungen durch die Verwendung eines nicht-linearen Vorhersagemodells für jeden der beiden unabhängigen Messkanäle berechnet wird.

5. Verfahren nach Anspruch 3 oder 4, bei dem jedes Modell angepasst werden kann und sich abhängig von der Menge des Prozessrauschens in den jeweiligen Messkanälen anpasst.

6. Verfahren nach einem der vorstehenden Ansprüche, bei dem beim Schritt des Kombinierens der beiden gemessenen Werte das Gewicht jedes Werts sich invers mit dem Quadrat des Unterschieds zwischen dem prognostizierten Wert und der Messung für diesen Messkanal verändert.

7. Verfahren nach Anspruch 6, bei dem die beiden gemessenen Werte gemäß der folgenden Formel kombiniert werden:

$$M = M_1 \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} + M_2 \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2}$$

wobei M_1 und M_2 die beiden gemessenen Werte und σ_1 und σ_2 die Unterschiede zwischen den beiden gemessenen Werten und ihren entsprechenden prognostizierten Werten sind.

8. Verfahren nach einem der vorstehenden Ansprüche, bei dem die prognostizierten Werte für die jeweiligen Messungen auf entsprechenden Modellen für die Messung der Parameter über die zwei unabhängigen Messkanäle beruhen.

9. Verfahren nach Anspruch 8, bei dem die Modelle Schätzungen für Prozessrauschen und Sensorrauschen für jeden der beiden unabhängigen Messkanäle beinhalten.

10. Verfahren nach Anspruch 8 oder 9, bei dem die jeweiligen Modelle voneinander unabhängig sind.

11. Verfahren nach Anspruch 10, bei dem die jeweiligen Modelle dieselben Schätzungen für Prozessrauschen und Sensorrauschen beinhalten.

12. Verfahren nach Anspruch 8, 9, 10 oder 11, bei dem die jeweiligen Modelle Kalman-Filter sind.

13. Verfahren nach einem der vorstehenden Ansprüche, ferner umfassend den Schritt des Entsorgens von Messungsreihen für die die Unterschiede zwischen den gemessenen Werten und ihren prognostizierten Werten einen festgelegten Schwellenwert für eine festgelegte Zeitspanne überschreiten.

14. Verfahren nach einem der vorstehenden Ansprüche, bei dem der Parameter die Herzrate ist.

15. Verfahren nach Anspruch 14, bei dem die beiden unabhängigen Messungen von einem Elektrokardiographen gemacht werden und eine Pulsoximetrie-Wellenform jeweils die beiden unabhängigen Messkanäle darstellt.

16. Verfahren nach einem der vorstehenden Ansprüche, bei dem es mehr als zwei Messungen gibt.

17. Computerprogramm, das Programm-Code-Mittel zum Ausführen des Verfahrens einer der vorstehenden Ansprüche umfasst.

18. Vorrichtung, die Parametermessmittel und Berechnungsmittel umfasst, wobei die Vorrichtung zum Ausführen des Verfahrens einer der Ansprüche 1 bis 16 konstruiert und angeordnet ist.

Revendications

1. Procédé de mesure par ordinateur d'un paramètre comprenant les étapes consistant à :

   prédire la valeur du paramètre,
   effectuer deux prises de mesure indépendantes du paramètre via un sur deux canaux de mesure respectifs afin de produire deux valeurs mesurées du paramètre, et
   obtenir une nouvelle valeur prédite du paramètre à partir des mesures ;

   caractérisé en ce que :

   l'étape de prédiction de la nouvelle valeur du paramètre comprend une prédiction de la valeur de chacune des deux mesures indépendantes du paramètre pour les deux canaux de mesure indépendants à l'aide d'un modèle de prédiction,

   et par les étapes consistant à :

   calculer les différences respectives entre les valeurs prédites et les valeurs mesurées respectives pour chacun desdits deux canaux de mesure indépendants, et
   combiner les deux valeurs mesurées pondérées par des coefficients de pondération déterminés par lesdites différences.

2. Procédé selon la revendication 1, les étapes de prédiction, mesure, calcul et combinaison étant répétées en continu, la valeur prédite pour chacune des deux mesures indépendantes reposant sur la précédente valeur prédite et sur la différence entre la précédente valeur prédite et la mesure précédente.

3. Procédé selon la revendication 2, la valeur prédite pour chacune des deux mesures indépendantes étant calculée à l'aide d'un modèle de prédiction linéaire pour chacun des deux canaux de mesure indépendants.

4. Procédé selon la revendication 2, la valeur prédite pour chacune des deux mesures indépendantes étant calculée à l'aide d'un modèle de prédiction non linéaire pour chacun des deux canaux de mesure indépendants.

5. Procédé selon la revendication 3 ou 4, chaque modèle étant adaptable et s'adaptant en fonction de la quantité de bruit de traitement dans les canaux de mesure respectifs.

6. Procédé selon l'une quelconque des revendications précédentes, où lors de l'étape de combinaison des deux valeurs mesurées, la pondération de chaque valeur varie inversement au carré de la différence entre la valeur prédite et la mesure pour ce canal de mesure.

7. Procédé selon la revendication 6, les deux valeurs mesurées étant combinées selon la formule :

$$M = M_1 \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} + M_2 \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2}$$

   M_1 et M_2 étant les deux valeurs mesurées et σ_1 et σ_2 étant les différences entre les deux valeurs mesurées et leurs valeurs prédites respectives.

8. Procédé selon l'une quelconque des revendications précédentes, les valeurs prédites pour les mesures respectives reposant sur des modèles respectifs pour la mesure dudit paramètre via lesdits deux canaux de mesure indépendants.

9. Procédé selon la revendication 8, les modèles comprenant des estimations concernant le bruit de traitement et le bruit de capteur de chacun desdits deux canaux de mesure indépendants.

10. Procédé selon la revendication 8 ou 9, les modèles respectifs étant mutuellement indépendants.

11. Procédé selon la revendication 10, les modèles respectifs comprenant des estimations identiques pour le bruit de traitement et le bruit de capteur.

12. Procédé selon la revendication 8, 9, 10 ou 11, les modèles respectifs étant des filtres de Kalman.

13. Procédé selon l'une quelconque des revendications précédentes comprenant en outre l'étape consistant à ignorer des séries de mesures pour lesquelles les différences entre les deux valeurs mesurées et leurs valeurs prédites dépassent un seuil prédéterminé pour une période prédéterminée.

14. Procédé selon l'une quelconque des revendications précédentes, le paramètre étant le rythme cardiaque.

15. Procédé selon la revendication 14, les deux mesures indépendantes étant effectuées à l'aide d'un électrocardiographe et d'une forme d'onde d'oxymétrie pulsée constituant respectivement lesdits deux canaux indépendants.

16. Procédé selon l'une quelconque des revendications précédentes, plus de deux mesures étant effectuées.

17. Programme informatique comprenant des moyens de code de programmation pour exécuter le procédé de l'une quelconque des revendications précédentes.

18. Appareil comprenant des moyens de mesure de paramètre et des moyens informatiques, l'appareil étant construit et agencé pour exécuter le procédé de l'une quelconque des revendications 1 à 16.

Fig.1.

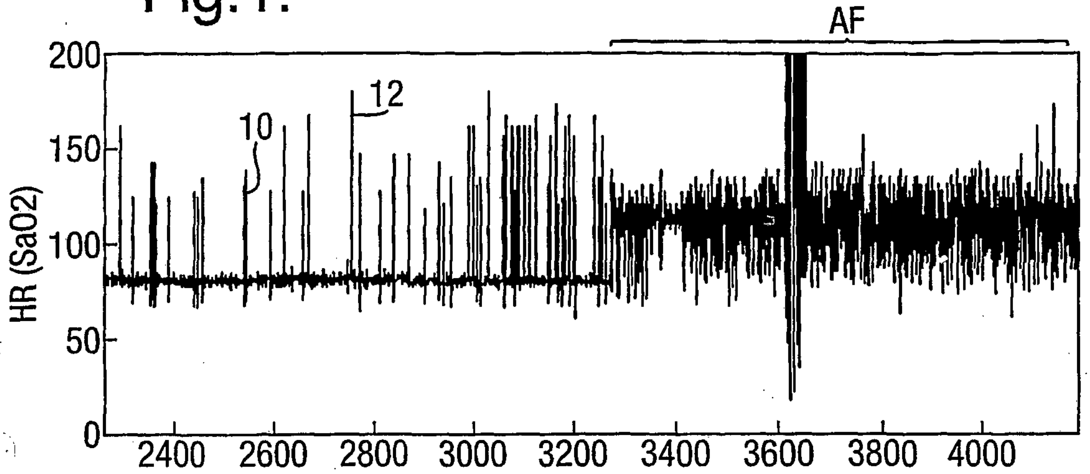


Fig.2.

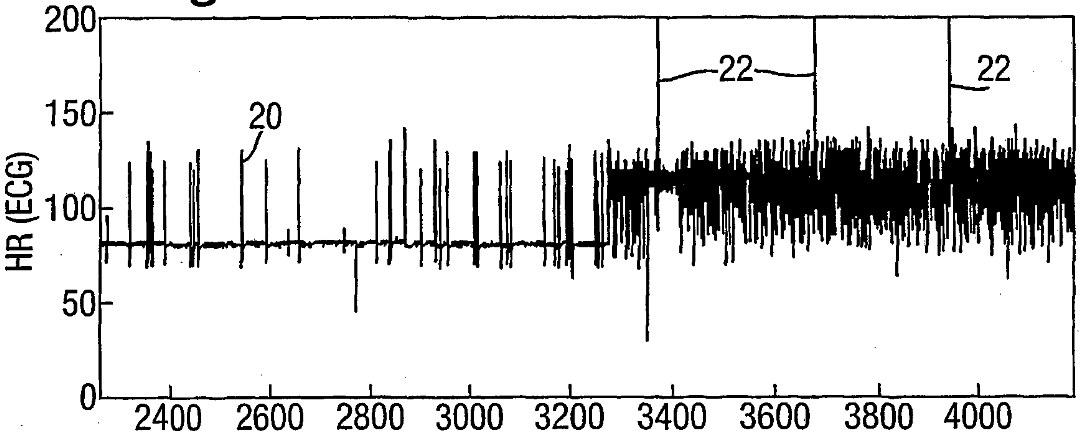


Fig.3.

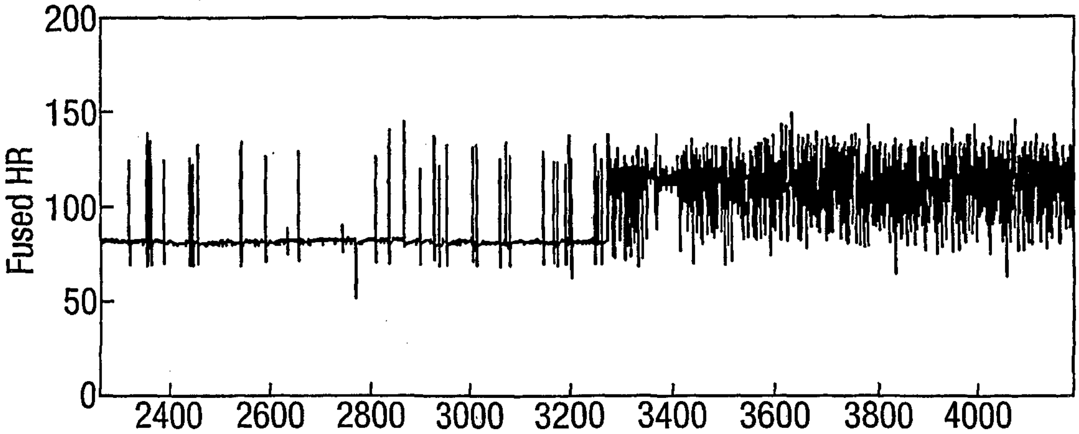


Fig.4(A).

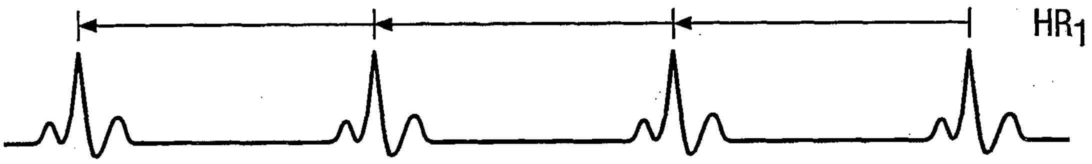


Fig.4(B).

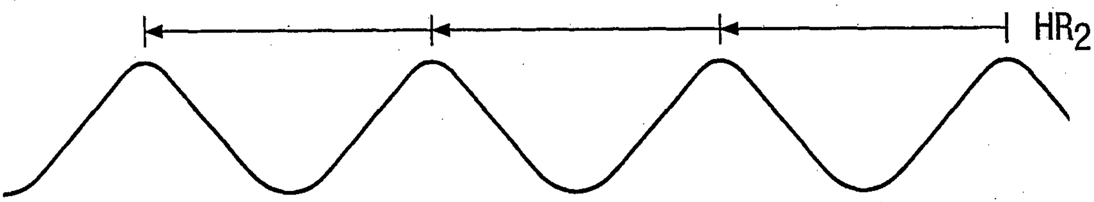


Fig.5(A).

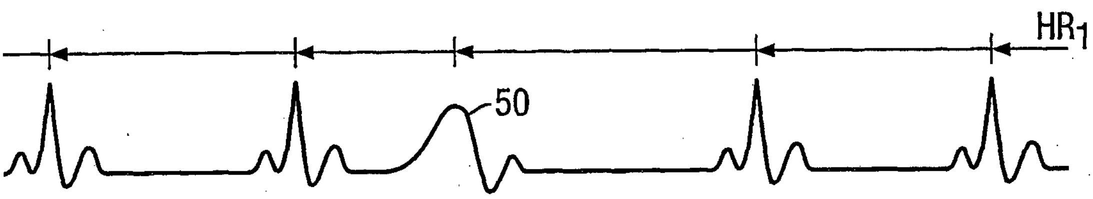


Fig.5(B).

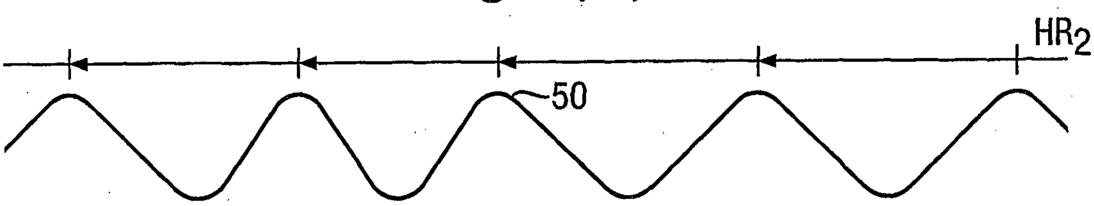


Fig.6.

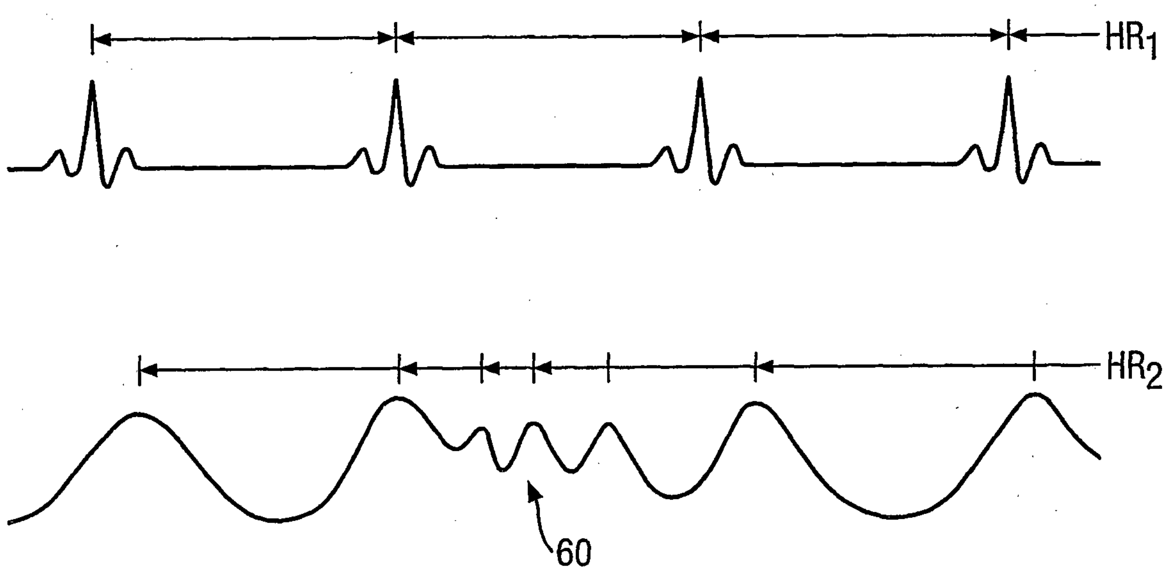


Fig.7.

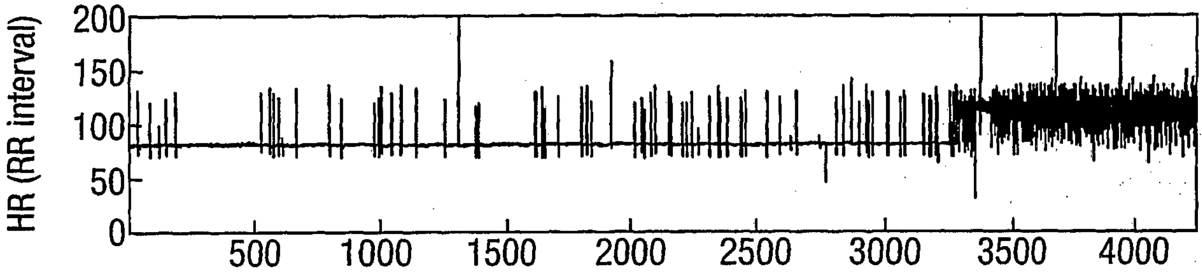


Fig.8.

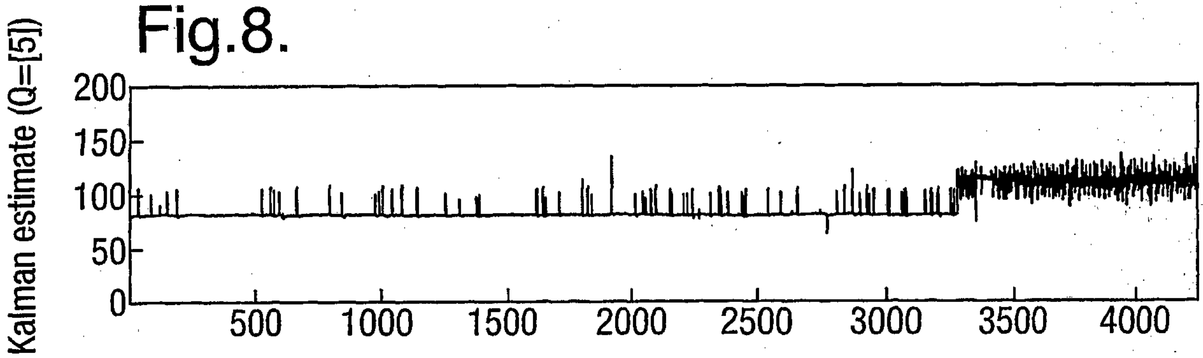


Fig.9.

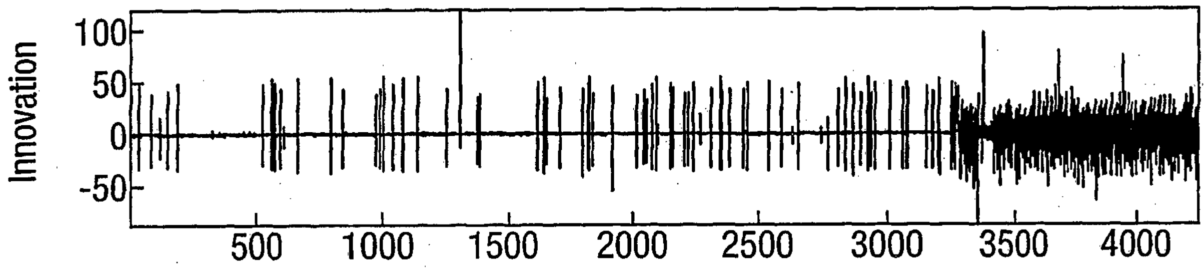
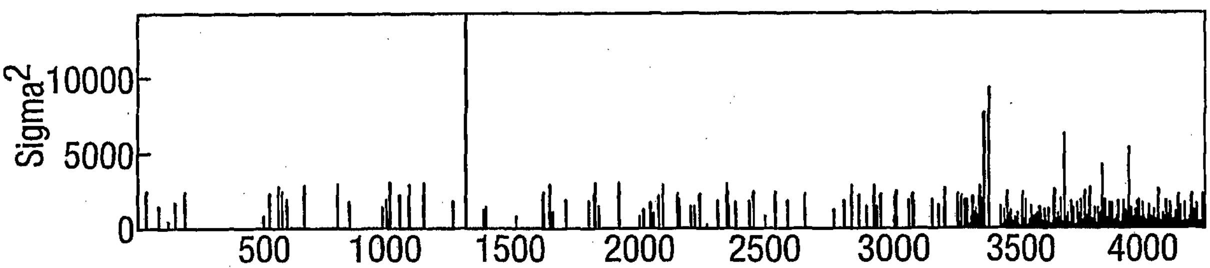


Fig.10.



REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 5626140 A **[0005]**

专利名称(译)	结合不同传感器的测量结果		
公开(公告)号	EP1316021B1	公开(公告)日	2016-08-24
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申请(专利权)人(译)	ISIS创新有限公司		
当前申请(专利权)人(译)	OBS医药有限		
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其他公开文献	EP1316021A2		
外部链接	Espacenet		

摘要(译)

一种用于组合来自两个或更多个独立测量通道的生理测量的方法，特别是诸如心率的生理测量。可以组合心率的独立测量，例如通过ECG和脉搏血氧测定法，以获得改进的测量，从而消除一个通道上的假象。产生生理参数的过程的模型，例如，为每个通道构建并独立运行心率，以生成参数的预测。该模型可以是卡尔曼滤波器。将测量值与预测值进行比较，并将差异用作测量置信度的指示，差异越大，置信度越低。使用根据所考虑的差异计算的权重组合来自两个通道的测量值。

$$M = M_1 \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} + M_2 \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2} \quad (1)$$