From Autonomic Computing Concepts Learned from the Heart System Towards Modelling Challenges in eHealth

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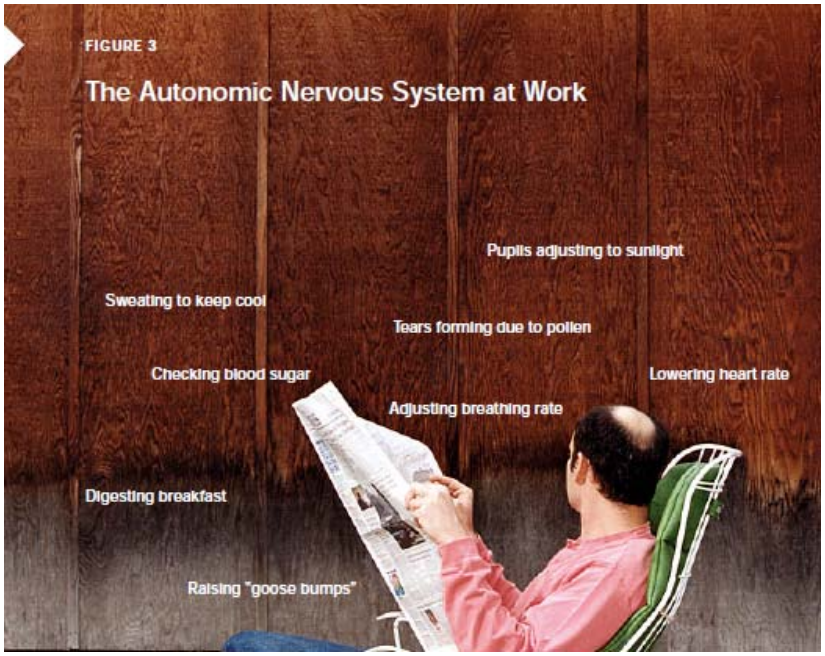
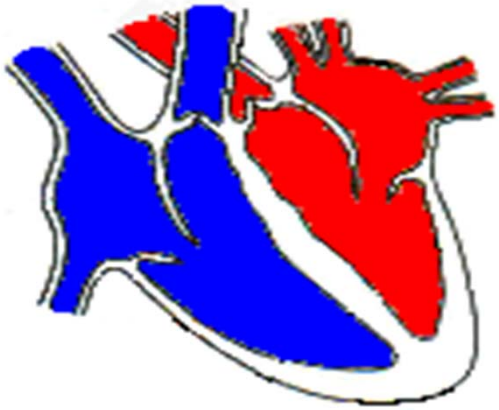
From Autonomic Computing Concepts Learned from the Heart System . . .

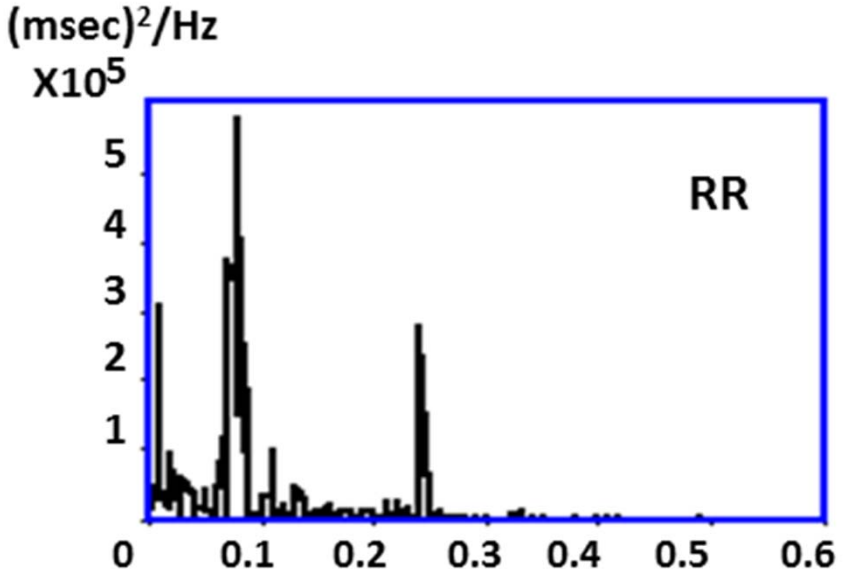


From Paul Horn. Autonomic computing: IBM's Perspective on the State of Information Technology. 2001



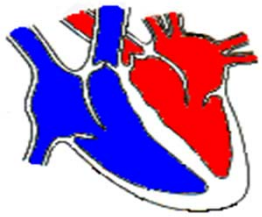
Interactions between :

- The cardiovascular system and the autonomic nervous system
- The sympathetic and para-sympathetic systems

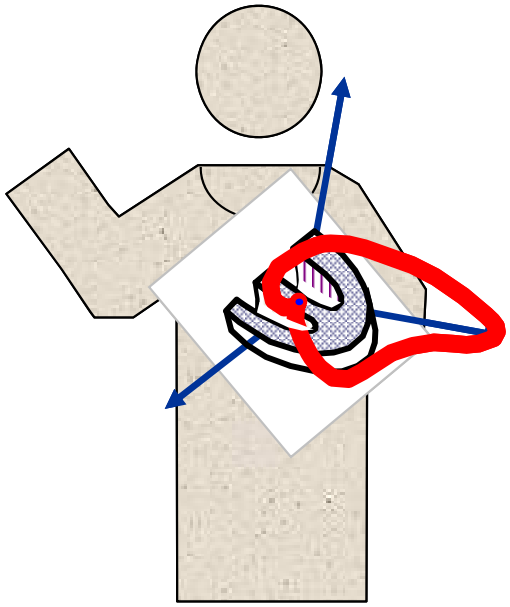


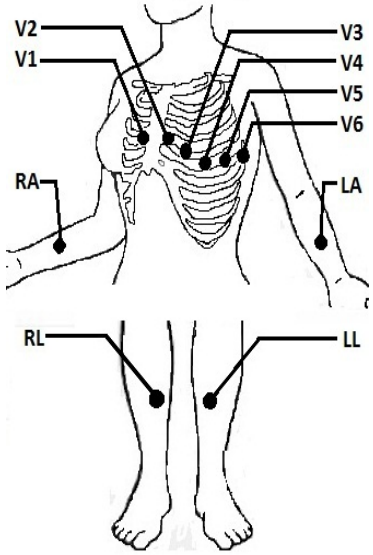
Power Spectrum Density of the RR interval, the inverse of the heart rate, from the electrocardiogram

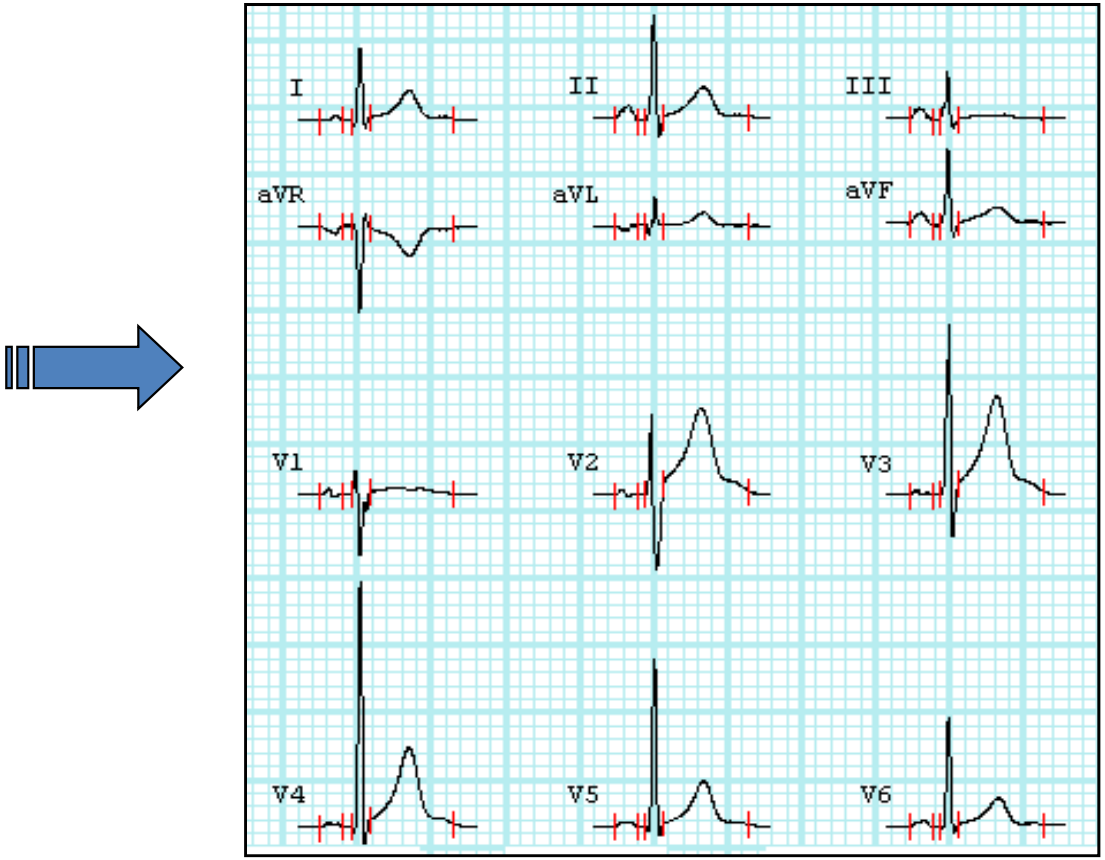
What is an electrocardiogram or ECG?



The heart is an electric generator that acts as a current dipole which results from the polarization-depolarization of the cardiac cells.







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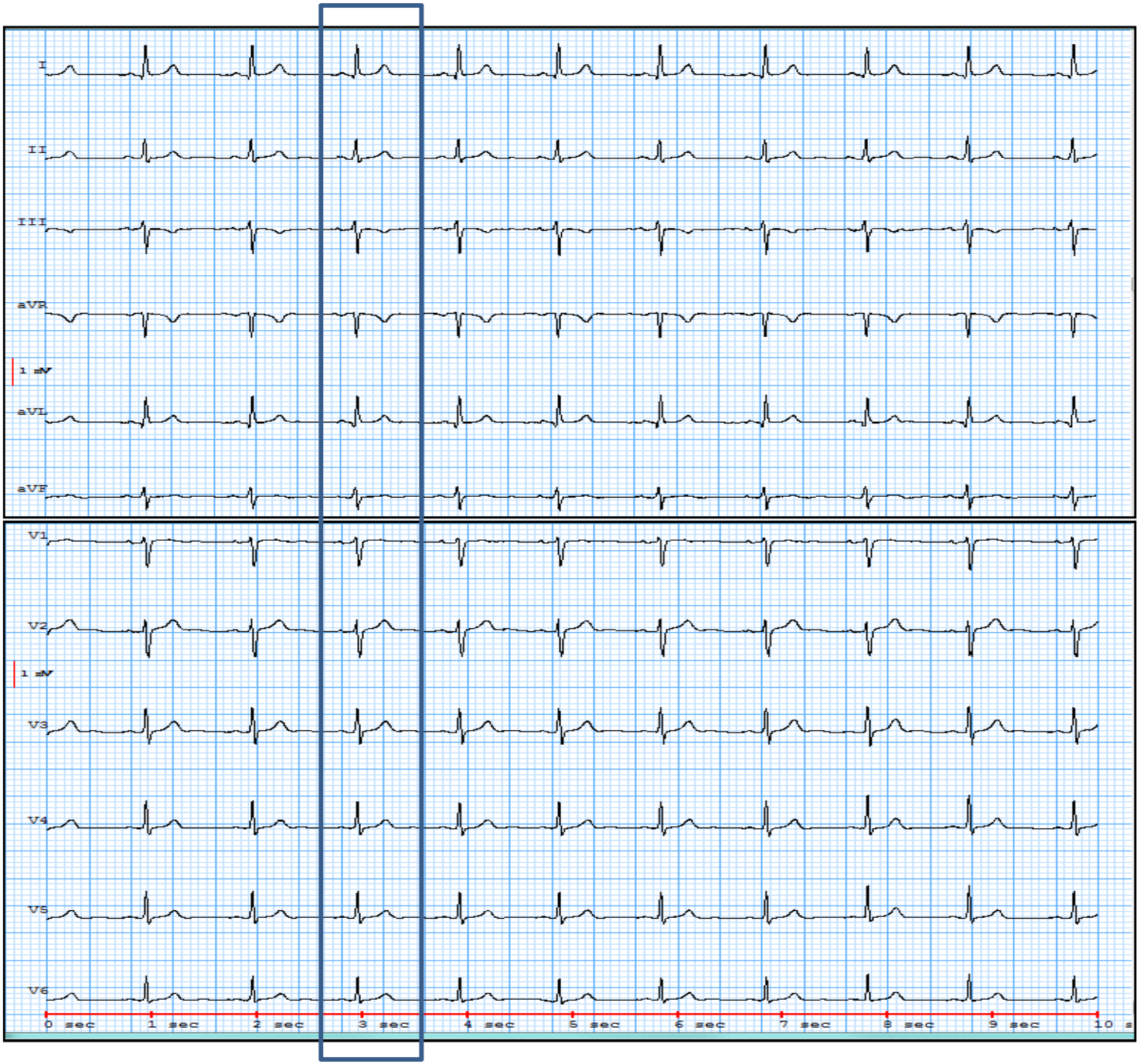
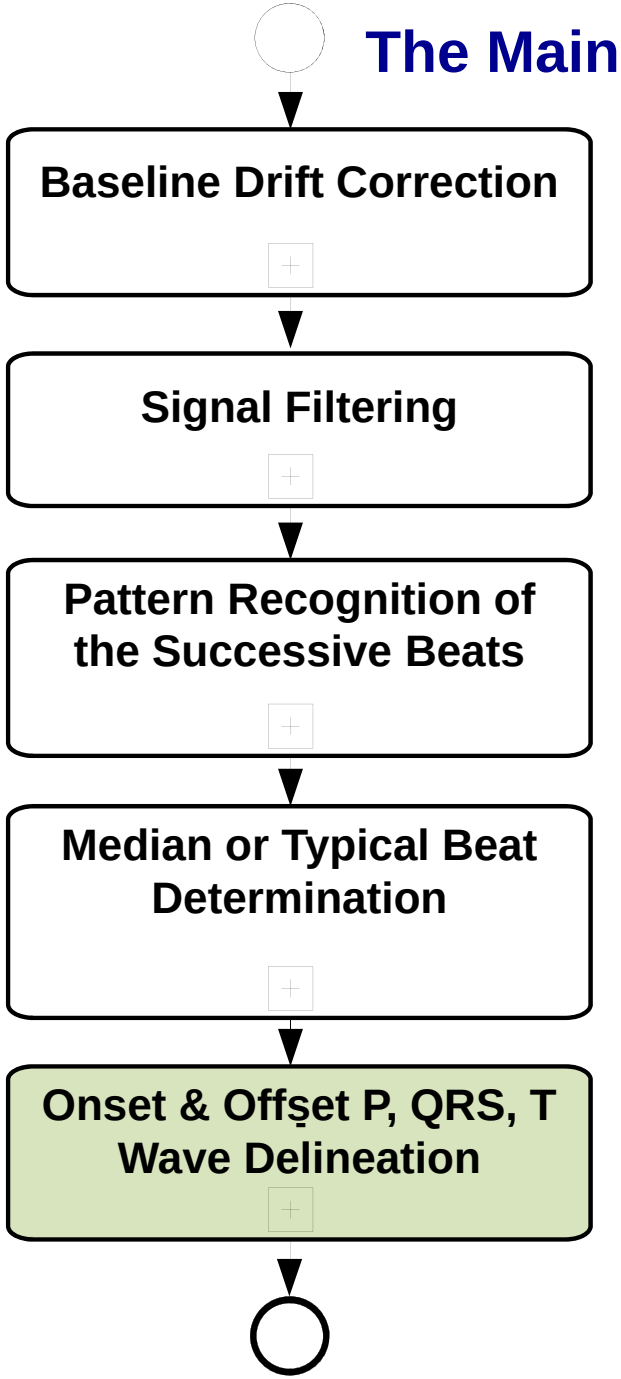
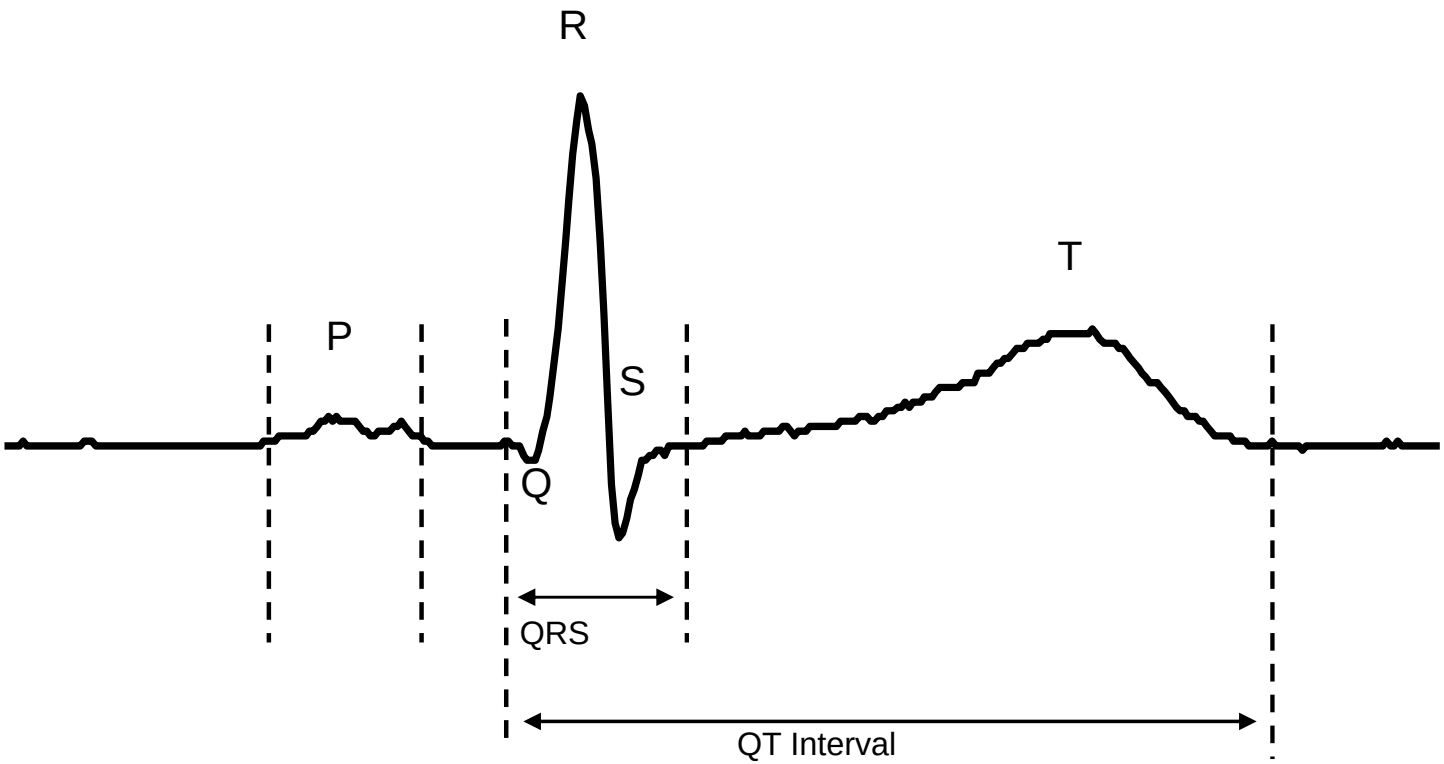


The Main ECG Processing Steps



The ECG signal was the first biological signal analyzed by computer



The Different ECG Waves from a Heart Beat:

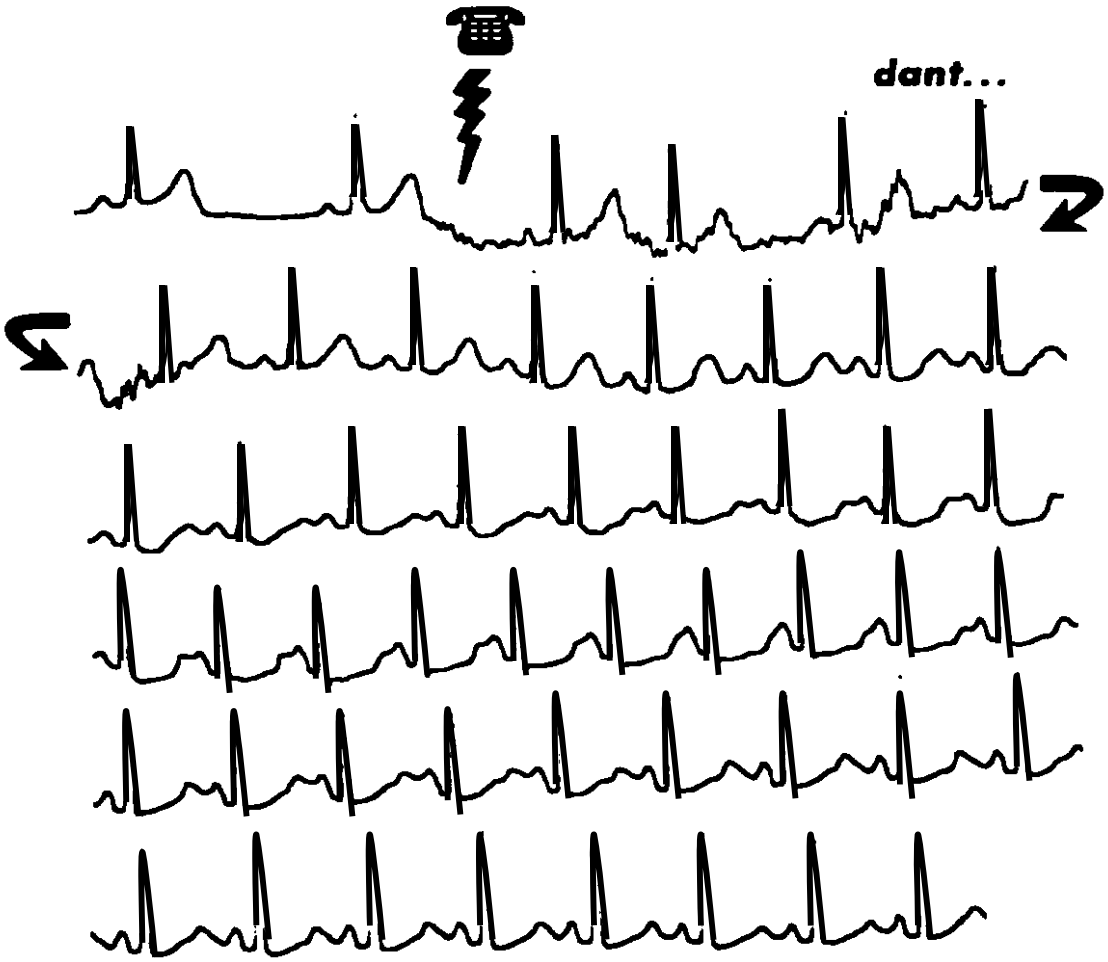
- **P** **Atrial Depolarization**
- **QRS** **Ventricular Depolarization**
- **T** **Ventricular Repolarization**

Some Figures about Heart Diseases

- Heart disease is one of the main causes of death in the world (World Health Organization)
- Because of the aging of the population, the number of cardiac deaths is steadily increasing
- Most of the cardiac deaths occur outside of the hospital

  The out-of-hospital to in-hospital health ratios range between 15.6 : 1 for the less than 50 to 2 : 1 for the elderly (more than 70)
- New strategies are needed to reduce the time before treatment.
- The ECG is still the main source of information for an early detection of cardiac events
- The ECG is easy to perform anywhere, at low cost. We have not yet extracted its information content, although a lot of research has been done.

What are the lessons ?



Snapshot of a continuous ECG recording. From Ph Coumel, Paris, France

Our vital system is context-aware.

Because it is self-adaptive, it is able to recover.

Self-governing avoids any damage thanks to the autonomic nervous system.

Balance between the sympathetic and para-sympathetic systems.

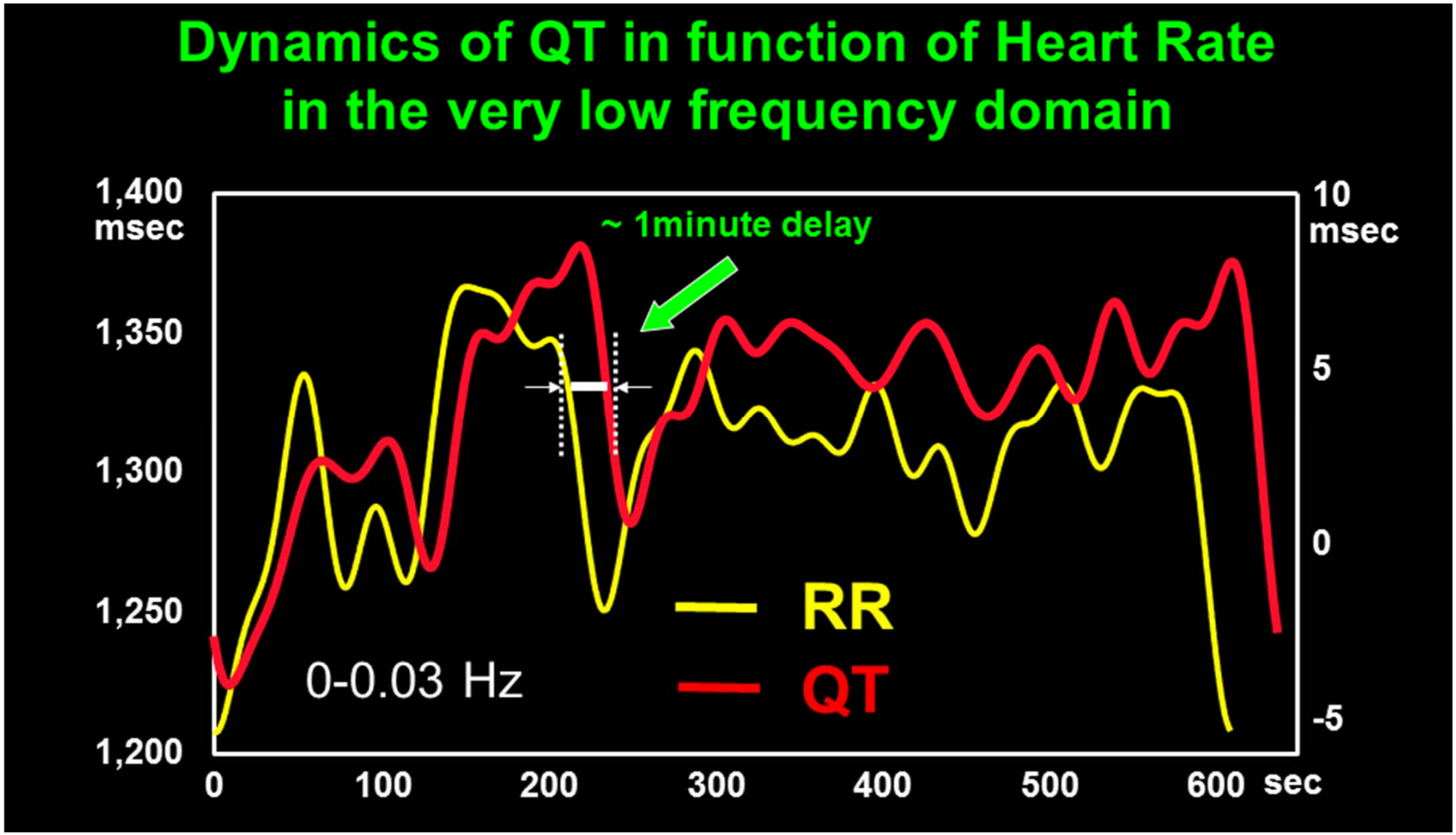
Because the telephone rings, there are sudden changes.

Another Figure of Heart disease

- **The number of sudden cardiac deaths is important, even in young adults.**

- **In the French Alps, the rescue teams and emergency services are called for about 350 myocardial infarctions each year.** (From Lucien Cadoz, ANPSP, National Association of 1st Aid in Mountains).

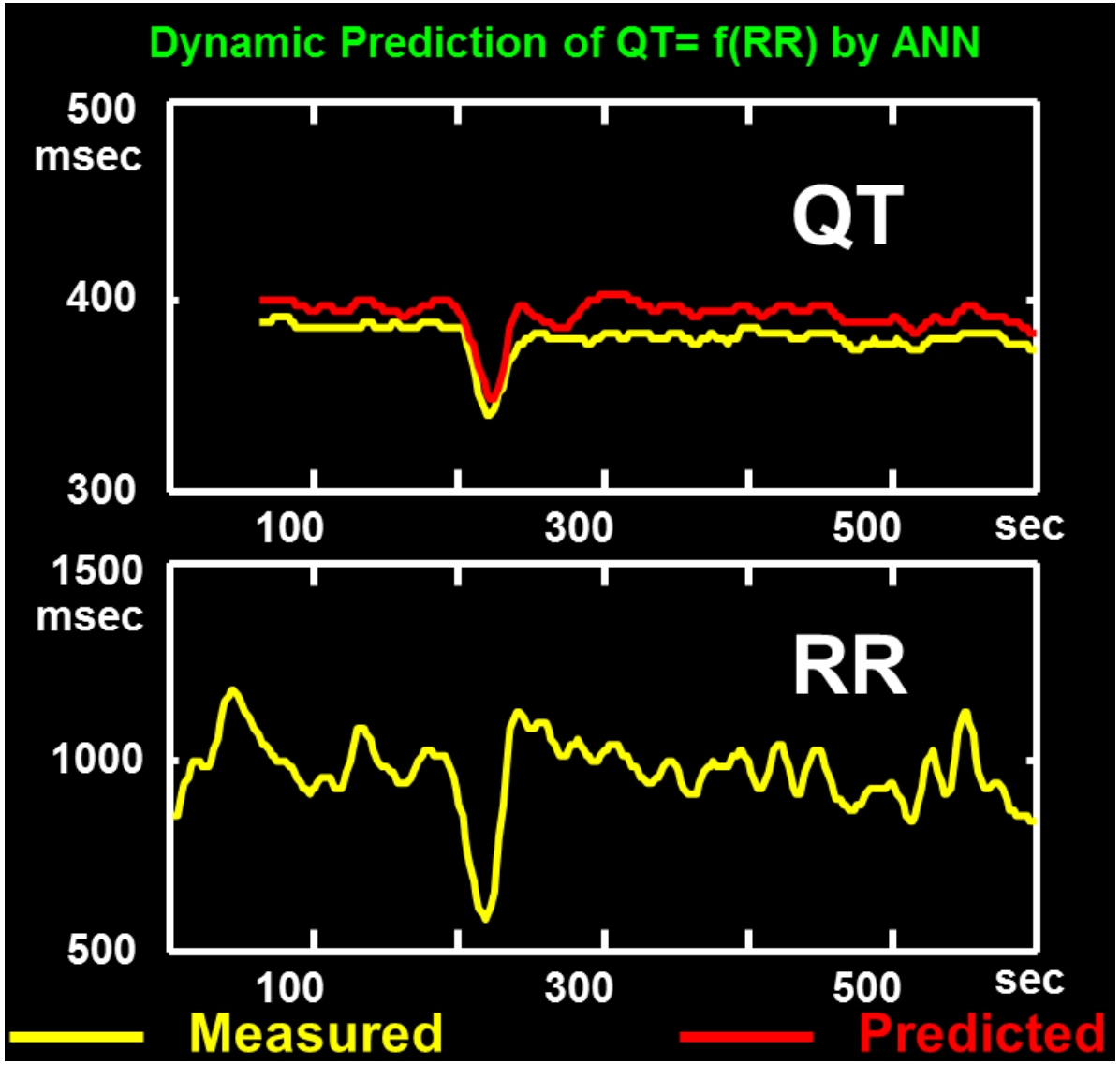
Self-Adaptation can be useful for cardiac risk prediction …



Inverse Fourier transform of QT and RR, in the very low frequency domain.

The values of QT are following the RR changes with a delay of about 1 minute.

Self-Adaptation can be useful for cardiac risk prediction

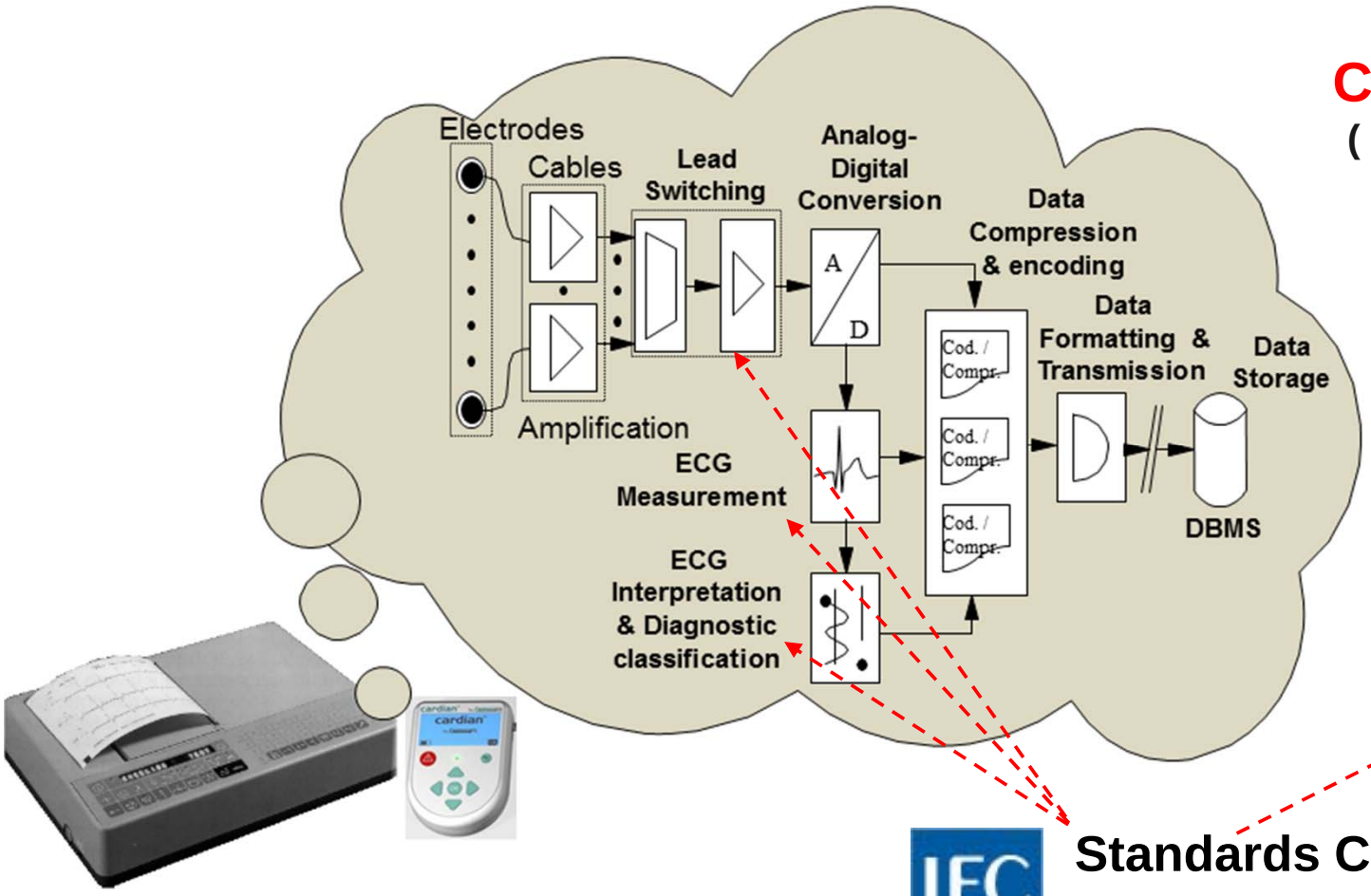


By using artificial neural networks, we can obtain a non-linear model of QT =f(RR) specific to each individual.

But, the ECG is quite stable along the life of an adult, when no cardiac disease occurs.

So, if we apply later on this subject, the previously learned model on his own measurements,
and if there are significant differences between the predicted and the measured values, it could be a sign of risk factor.

ECG **Self-Learning** could thus provide a wealth of information for cardiac risk prediction.

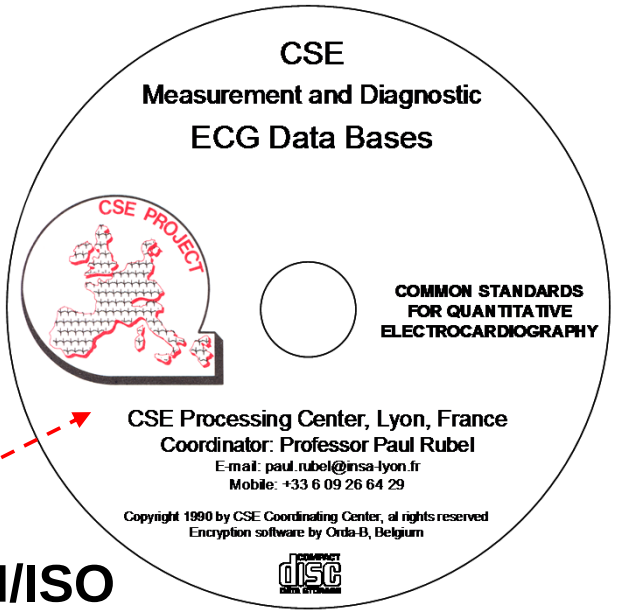


CSE Database Delivery

(~ 175 user teams in the world)

Contact :

prubel.lyon@gmail.com



Standards CEN/ISO

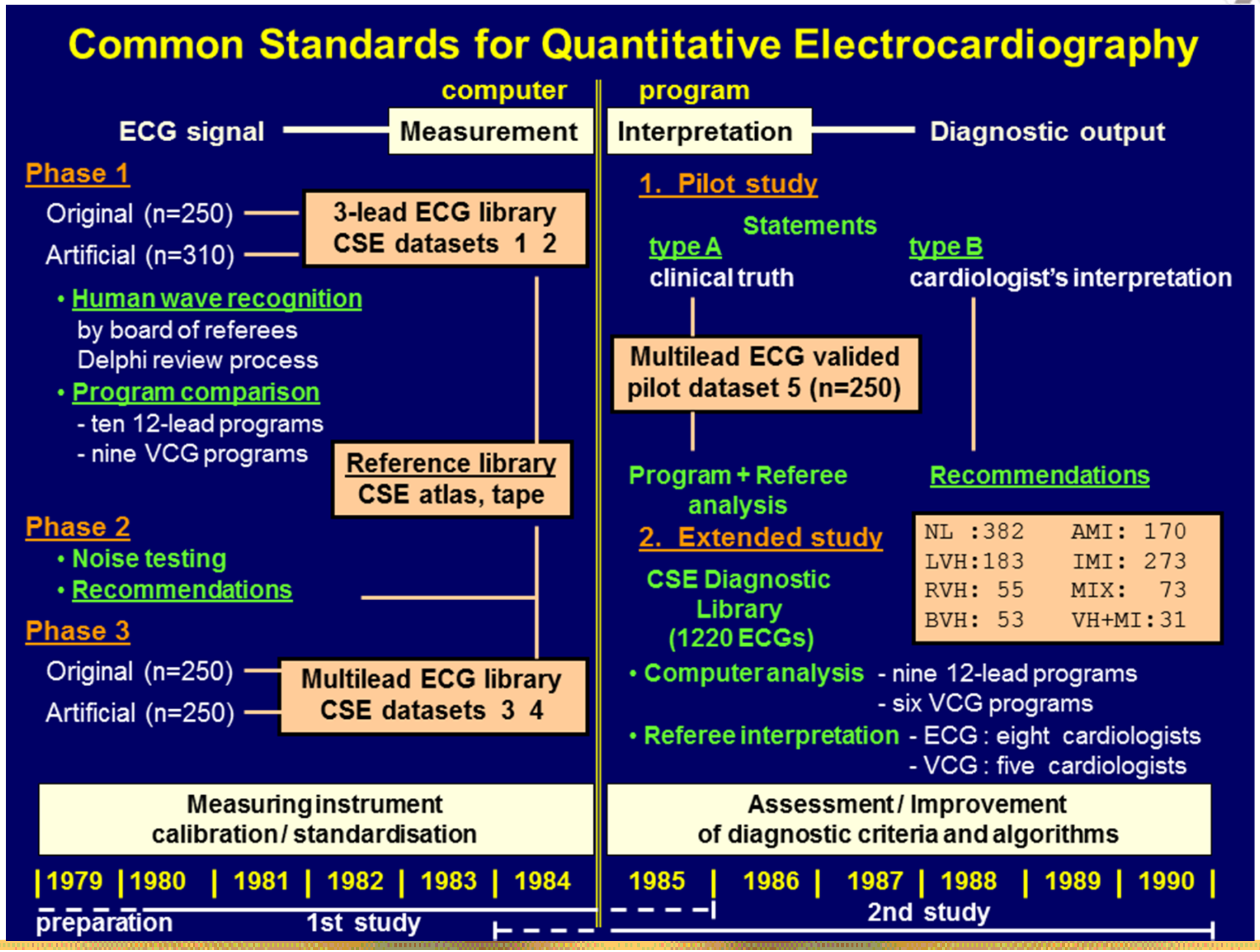
IEC 60601-2-51:2003

IEC 60601-2-25:2011

Common Standards for Quantitative Electrocardiography

Willems et al.: New Eng J of Med,325, 1991: 1767-73

From Autonomic Computing Concepts Learned from Digital ECG . . .



CSE ⇒ ECG unary Diagnosis < 80 %

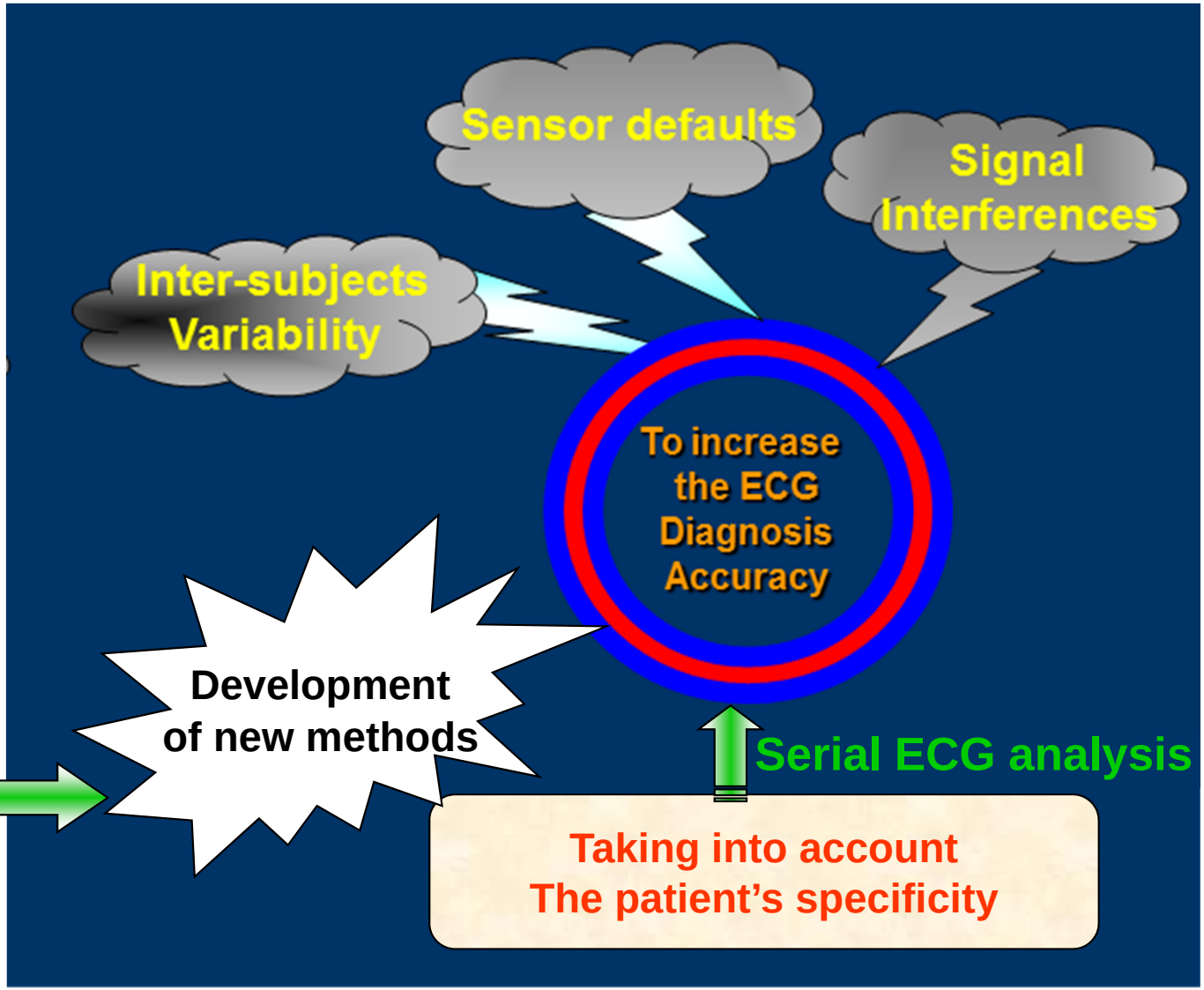
Why?

The main reason is inter-suject variability:
The human physiology is very diverse: Richness!

But, the ECG signal pattern is invariant during the life of each adult if no cardiac event occurs.

So, if there are ECG changes, it is an indication of a cardiac problem.

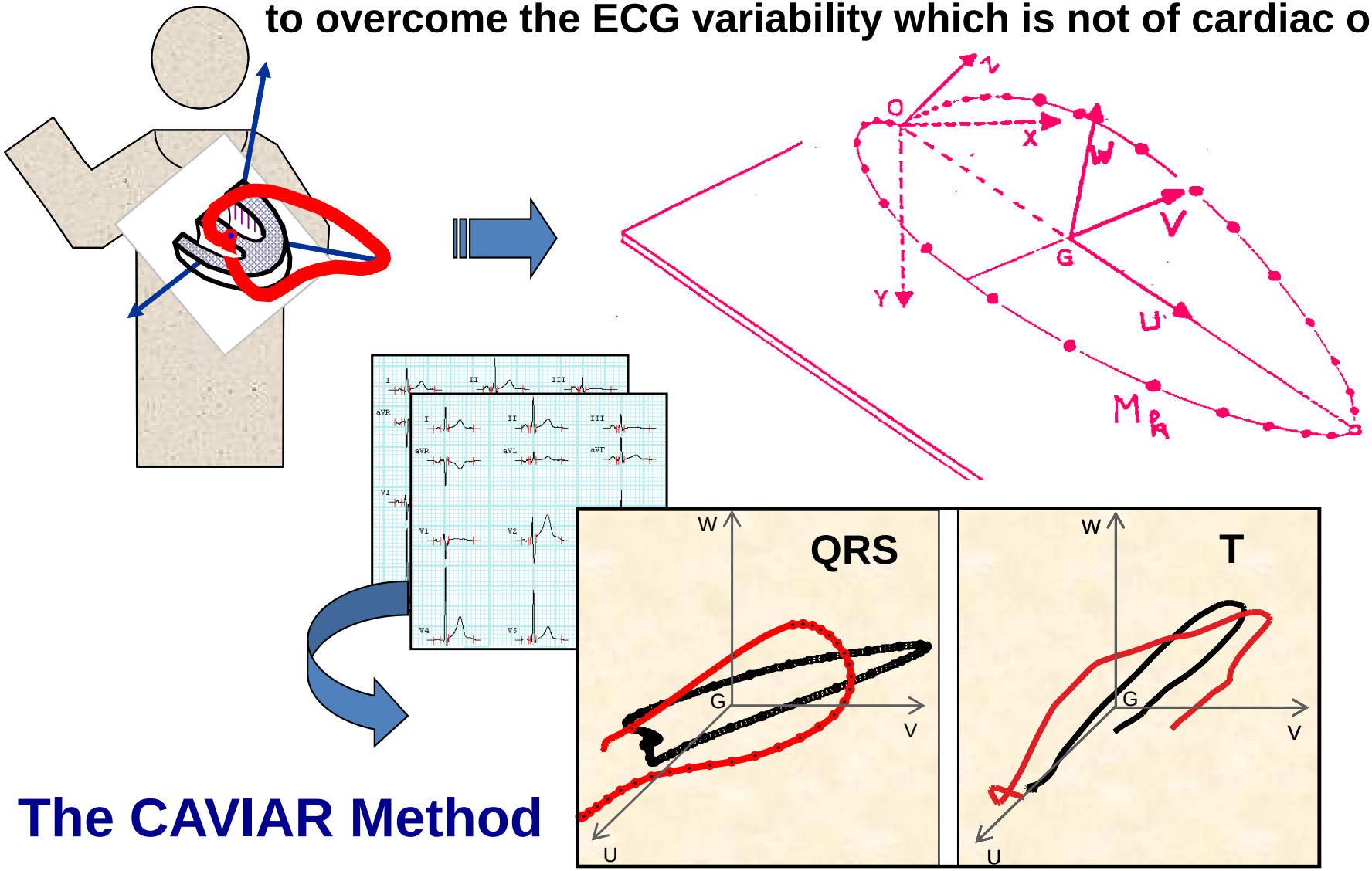
The ECG is a fingerprint!



How to improve? ⇒ **Recommendations to perform Serial ECG analysis**

Self-Reference ⇒ Self-Representation

Taking the heart system of the patient as its own reference system to overcome the ECG variability which is not of cardiac origin



The CAVIAR Method

Self-Reference & Self-Representation

- Measurement of **QRS duration changes** at 1 month interval in a 720 healthy subjects population (~20 years old) **decreased ~ 60% in average.** 90% of the values are less than one sampling interval. Similar results are obtained for the QT interval.

- **Improvement of diagnosis accuracy of ischemia:**

	Conventional ST criteria		Spatiotemporal CAVIAR criteria
SENSITIVITY (%)	60.0	+ 37.7 %	97.7
SPECIFICITY (%)	87.8		95.5
TOTAL ACCURACY (%)	73.9	+ 22.7 %	96.6

Each adult should have a reference ECG

Self-Representation

SCP-ECG: Standard Communications Protocol for Computer-Assisted Electrocardiography

European Norm
EN 1064:2005+A1:2007

ISO Standard
ISO/FDIS 11073–91064:2009

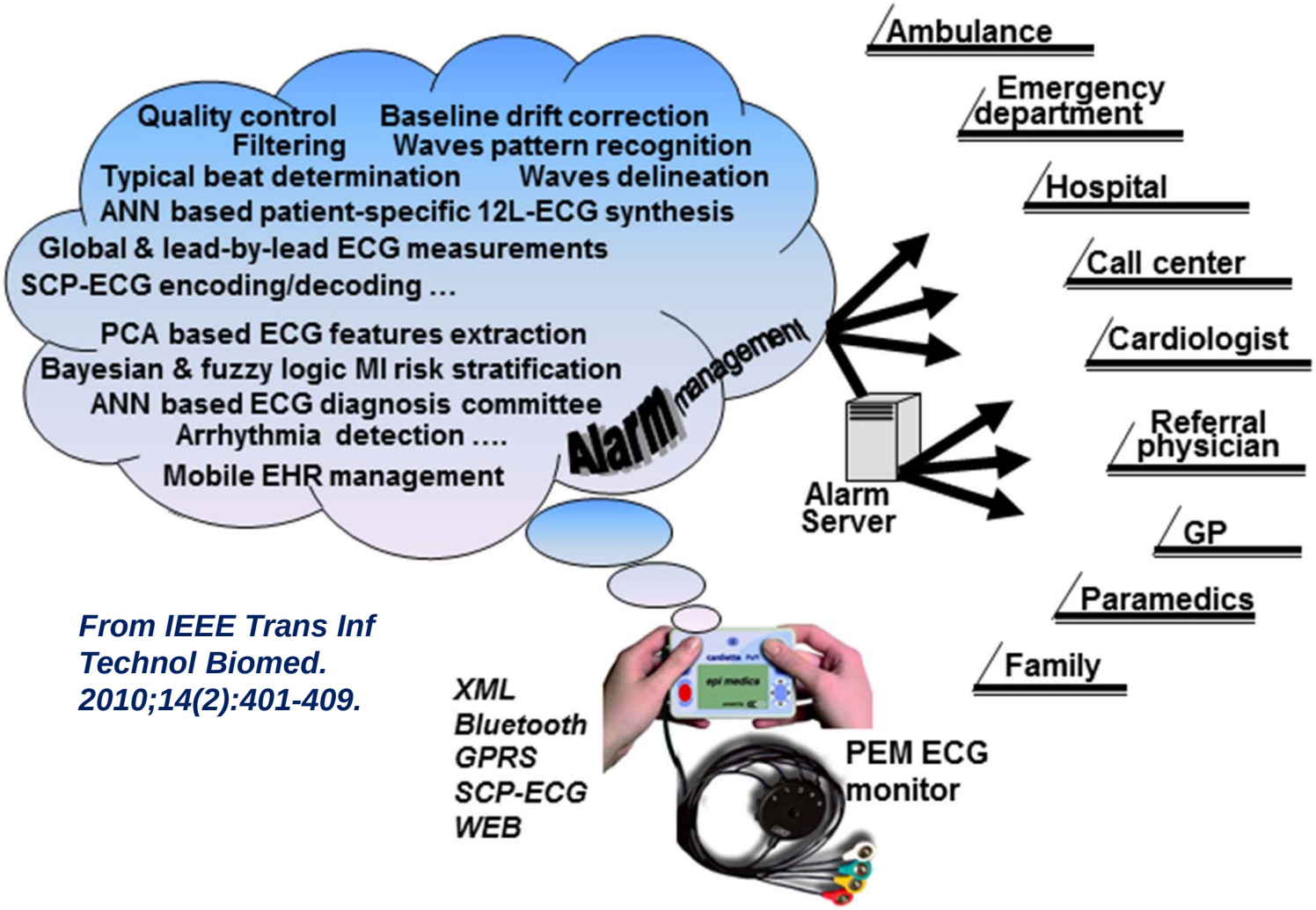
- S1 : Patient Data / ECG Acquisition Data
- S2 : Huffman tables used in encoding of ECG data
- S3 : ECG lead definition
- S4 : QRS locations
- S5 : Encoded median data
- S6 : Residual signal or encoded rhythm data
- S7 : Global measurements
- S8 : Textual diagnosis from the interpretive device
- S9 : Manufacturer specific diagnostic & overreading data
- S10 : Lead measurement results
- S11 : Statement codes resulting from the interpretation

An open Protocol

mHealth: mobile Health and pHealth: personalized Health

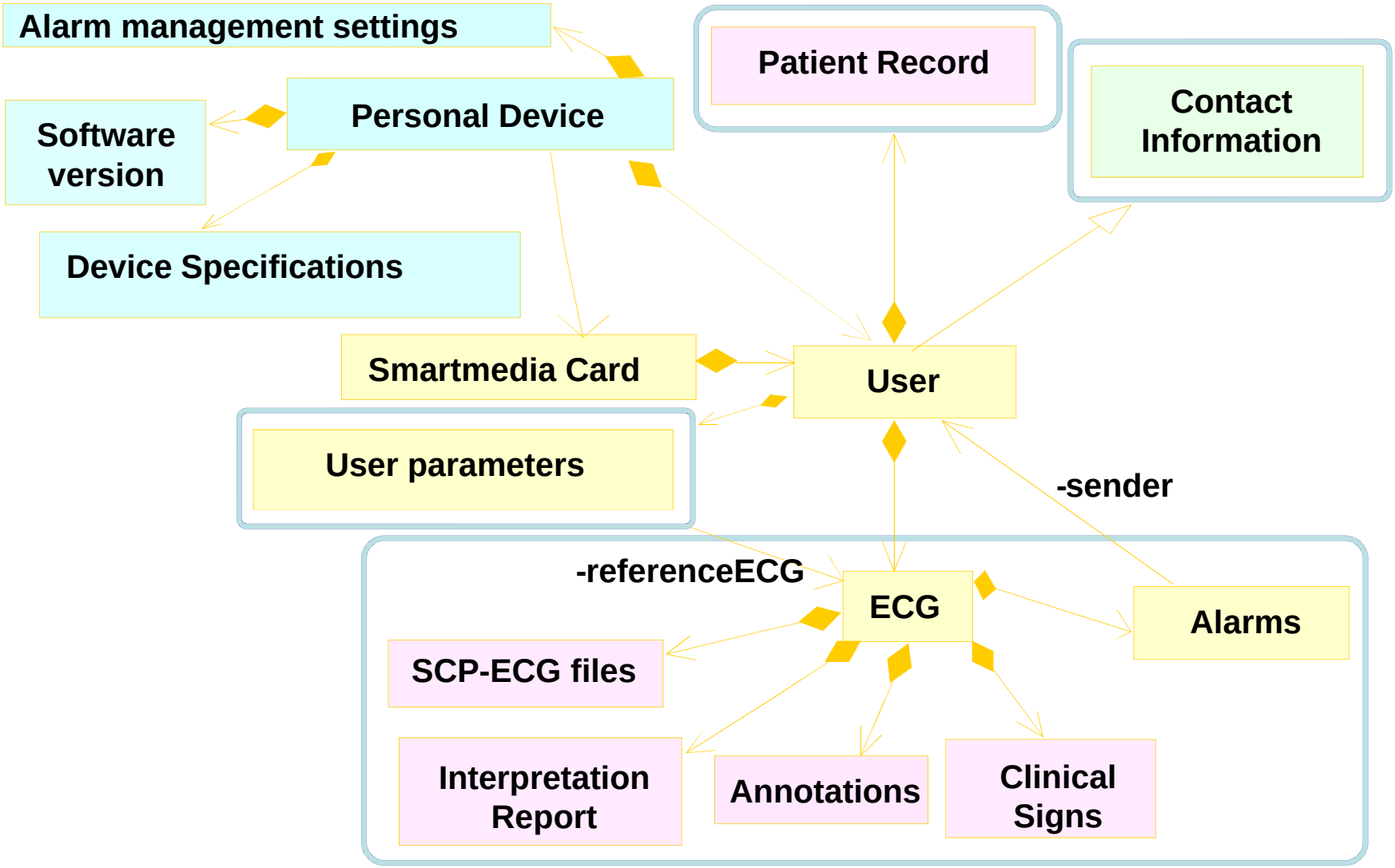
A Personal Health System for an early detection of cardiac events to reduce the time between the first symptoms and the hospital admission

- ✓ It allows any citizen to record himself his own ECG anywhere and at any time.
- ✓ It's an intelligent system with advanced ECG analysis and automatic interpretation.
- ✓ It embeds a web server to make the data available via a web browser from any computer of any physician who has the access rights.



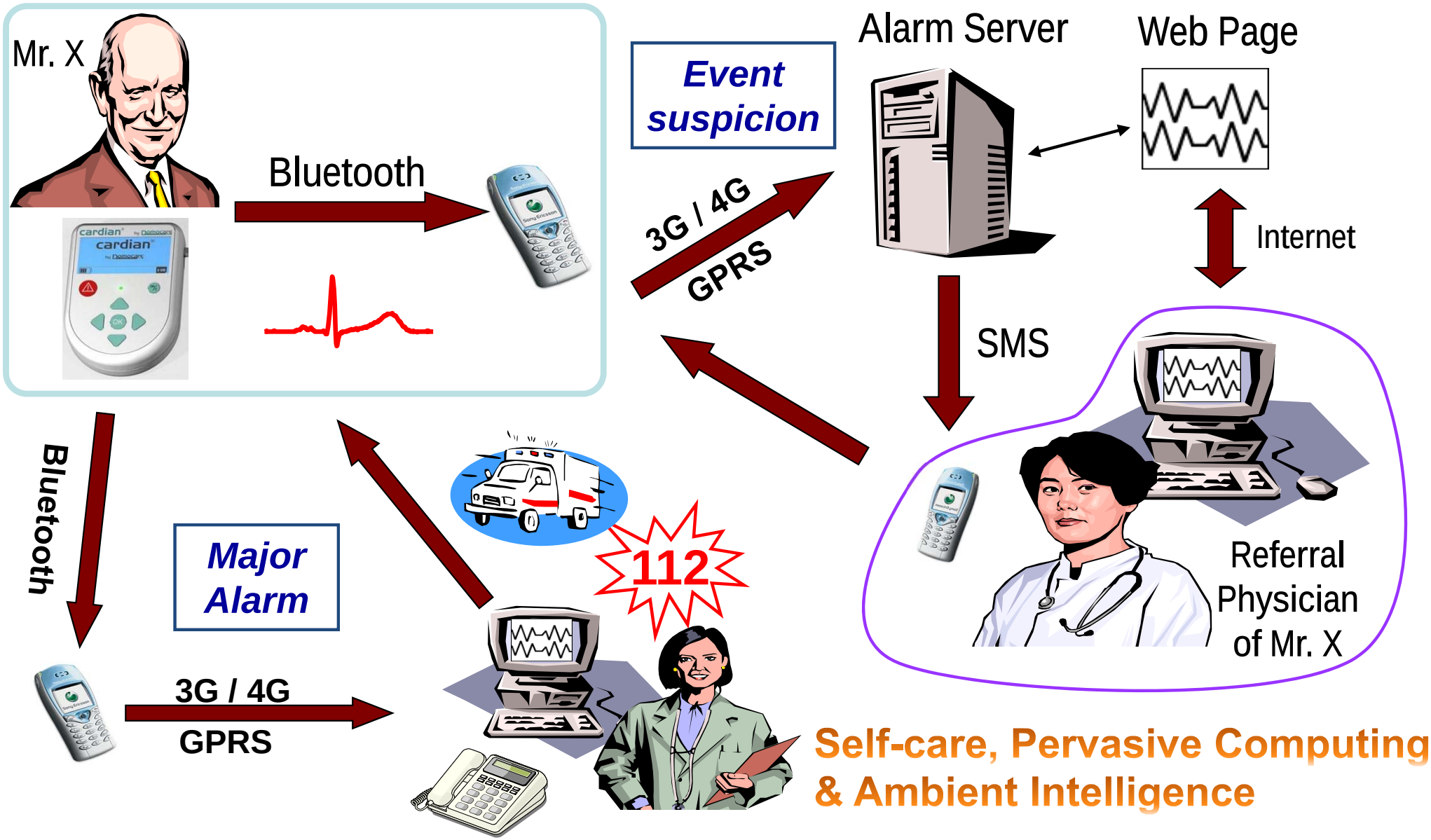
From IEEE Trans Inf Technol Biomed. 2010;14(2):401-409.

mHealth: mobile Health and pHealth: personalized Health



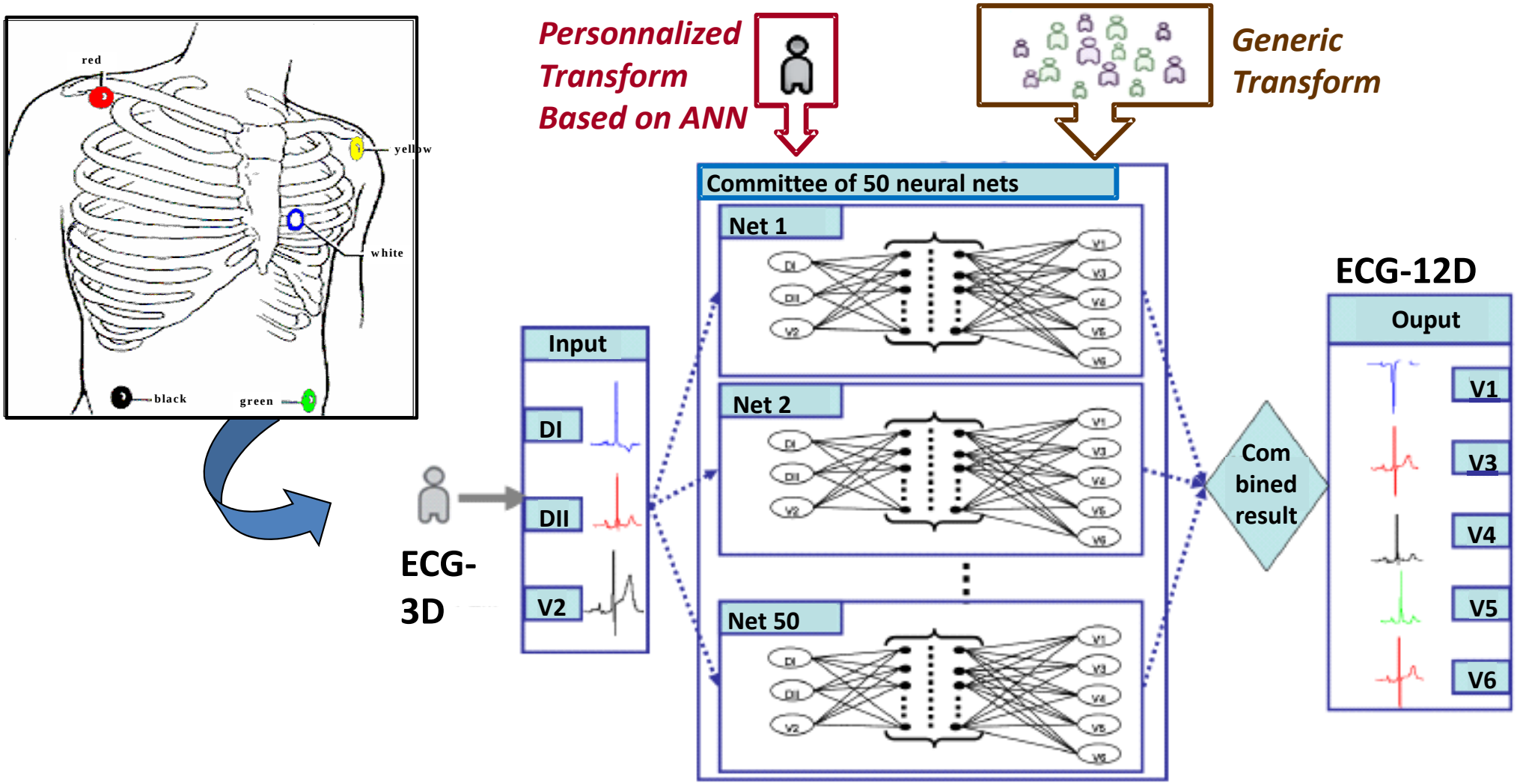
Snapshot of the Information Model embedded in the Personal Health System

mHealth: mobile Health and pHealth: personalized Health



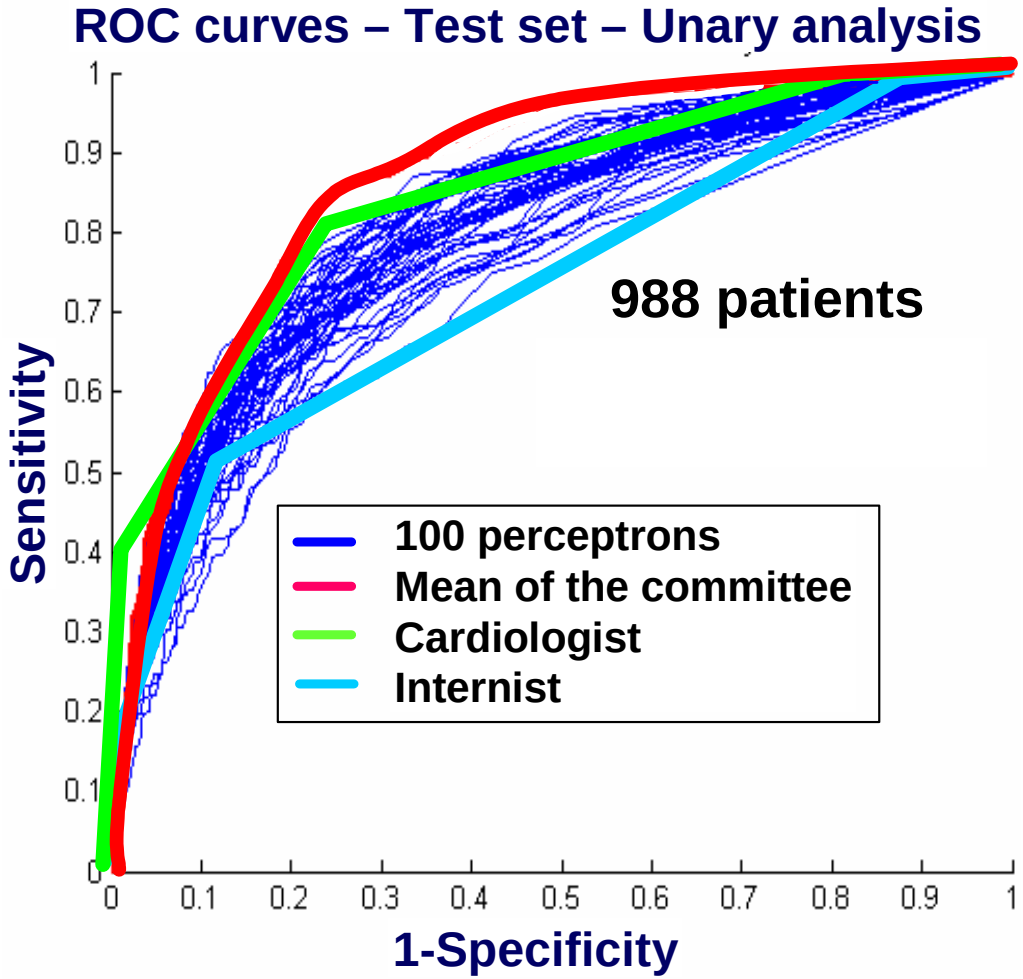
Self-Care and Self-Recording in pHealth

Self-Reference and Central Limit Theorem



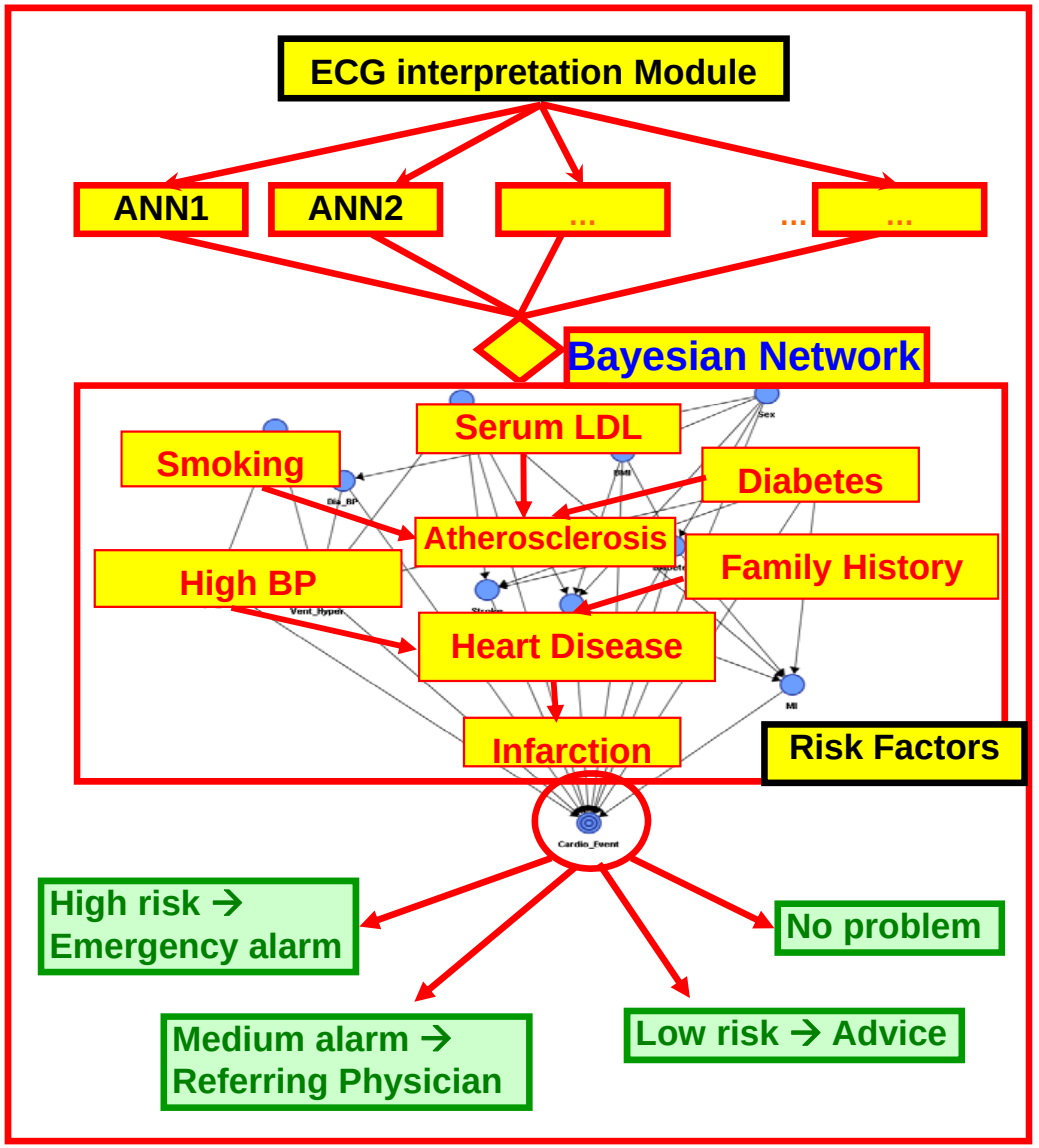
Autonomic and Grid Computing for Enhanced pHealth

Example of ECG autonomic decision-support performance in an emergency department for infarction detection ⇨ Healthgrids for learning phase



From Ohlson et al., Am. J. Cardiol., 2001 and Atoui et al., IEEE CISIS 2008: 583-8

pContext-Awareness



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"The most widely recognized elements of autonomic systems are the so-called self-* properties", *Dobson et al. , Computer, IEEE Press, 2010*

What are the lessons & future challenges ?

- **Concepts of context awareness and self-adaptation of the heart system**
  - **Self-governance of QT measurements in function of heart rate**

    The memory effect used for self-learning model design is fruitful for event risk prediction
- **How can self-recording (or self-monitoring) in self-care in pHealth improve the quality of life, the quality of service for well-being ?**
  - **Personalized health is a great challenge todays with a lot of research in this field, from sensors technology, up to quality of service for decision delivery**
  - **False alarms must be reduced as much as possible. But, in medicine the human experts as well as the machines are not perfect**
- **How could the machine, as well as the human, benefit from its past experience ?**
  - **Self-experimenting by self-learning leads to self-improvement.** (ANN, KBR, CBR, …)

From Autonomic Computing Concepts Learned from the Heart System Towards Modelling Challenges in eHealth

What are the lessons & future challenges ?

- **Personalization in pHealth is not just self-configuring or customization**
- **Concept of self-reference for serial ECG analysis and personalized ECG synthesis**
  - **Taking the individual as his own reference improves the results.**
- **Self-reference, the best model of personalization to empower autonomic computing ?**
  - **The first step of the system design is to well define the scope of the problems and to come back to the source of the information which is considered.**
  - **This information has to be assessed into its own reference system. That leads to develop mathematical methods of self-representation of the analyzed data** (ex. PCA in statistics where data are analyzed in their own space).
  - **The constraint to assume is the capability of the system to continuously change the representation system or information model according to the data dynamicity**
    → A challenge at run-time.

What are the lessons & future challenges ?

- **Enhance automated decision by using Committees of experts or reasoners**
  - **Use several methods or business process architectures in parallel to get the same decision. Taking the result of the majority vote will enhance the response.**
- **Enhance the capabilities of Anticipation: a future challenge ?**
  - **For a prompt delivery of the relevant information, the user needs should be determined before the user expresses them.**
  - **Real time dynamic context analysis should contribute to reach this objective.**
  - **User habits and preferences tracking should contribute to provide personalized anticipated services.** (Ex. of MMI in healthcare to overcome the physician's overload of information while browsing the medical records for finding the relevant data).
- **Enhance Embedded Intelligence**
  - **Automation of dynamic information and knowledge models merging, driven by the citizen's data and by artificial intelligence methods, in real time.**

Thank You for Your Attention

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