Biomedical sensors data fusion algorithm for enhancing the efficiency of fault-tolerant systems in case of wearable electronics device

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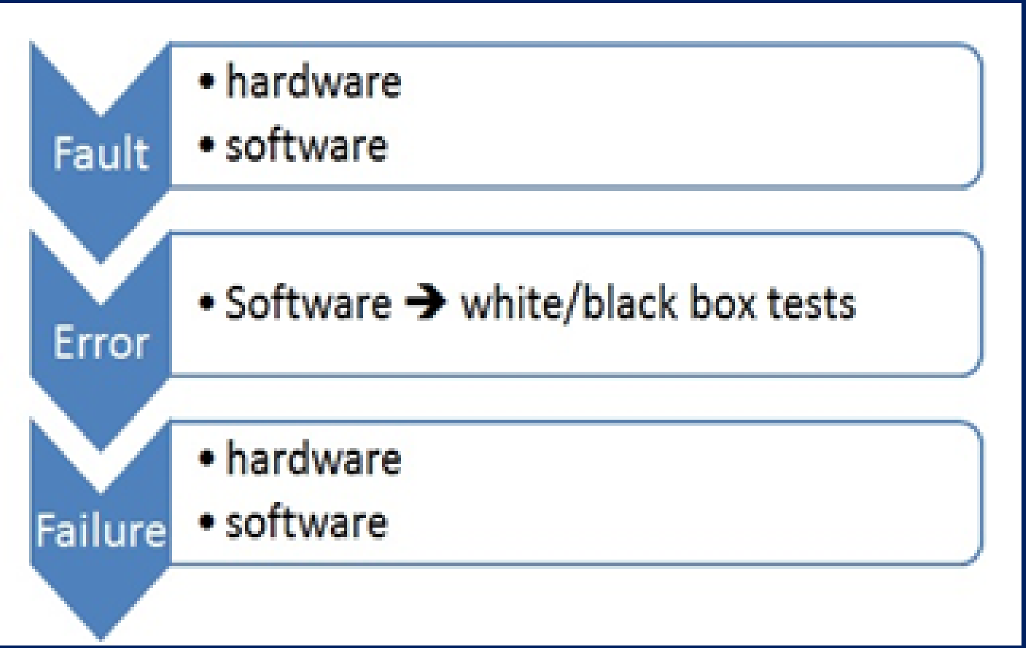
➔ **Multisensor data fusion and big data integrated in complex systems for security or healthcare can lead to system failure, fault or errors.**
➔ **Fault tolerance is an essential attribute for systems used in safety-critical applications like healthcare.**

➔ **Faults cause errors;**
➔ **errors cause failures effects;**



Cause-Effect diagram for fault-error-failure

Risk Factors for failure:

➔ **high complexity of control schemes** (variables, parameters and interconnections
➔ **miniaturizations and cost reductions** for components
➔ **Redundancy** of components (sensors)
➔ **Network control systems design** (“package loss” and “communication delay”)

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➔Fault means a physical defect or imperfection that occurs in some hardware (sensors, actuators) or software component (a short circuit between two adjacent interconnects, a broken pin, or a software bug)

➔Error means something incorrectly and inaccurately in computation, which occurs as a result of a fault (a circuit or a program computed an incorrect value, incorrect information received by data transmission).

➔Failure is something which does not function properly as expected (a system fail when does not work in accordance with the specification or due to the incorrect specification)

Critical applications systems for healthcare and security must be high reliable by designing systems which are fault-tolerant.
In case of wireless sensors, for healthcare application, nodes failures can be negative for critical or safety related systems.

➔For systems reliability improvement can be used a fault-tolerant sensor node based on Markov models for characterizing wireless sensors nodes reliability and mean time to failure.

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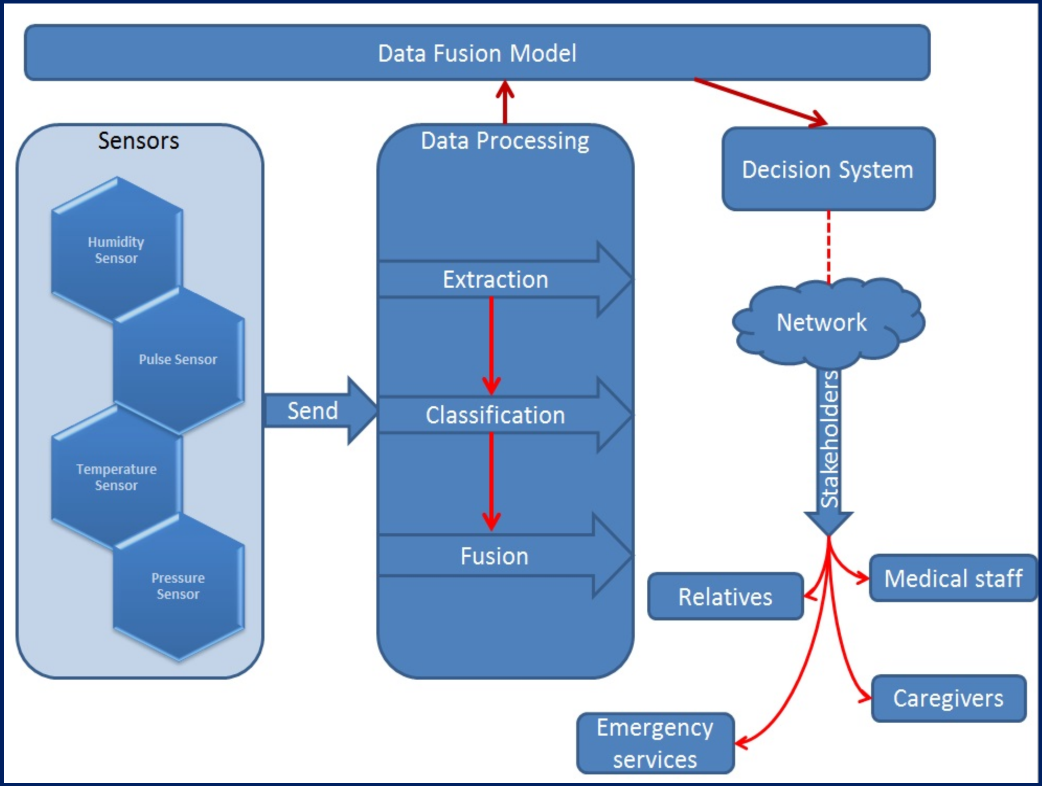
CASE STUDY: Wearable sensors from diabetic patients.

➔ 2 critical events that we considered – hyperglycemia and hypoglycemia

Hypoglycemia=f (temperature, pulse, breath rhythm, pulse)
Hyperglycemia=f (temperature, pulse, breath rhythm, pulse)

- ➔ Design sensor network
- ➔ Real-time sensor data processing
- ➔ Multisensor data fusion
- ➔ Predictive models for optimization (based on MPC algorithm);
- ➔ Results for decision or system alerts



Multisensor data fusion model

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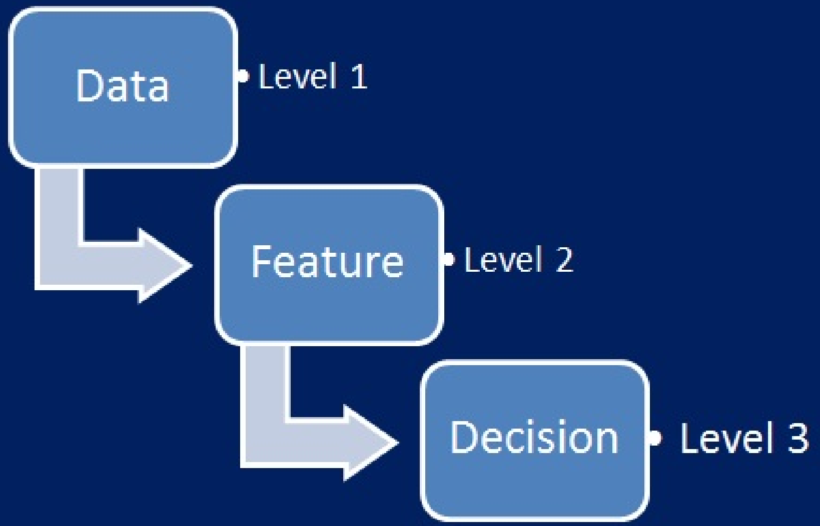
The fusion of multisensory data can be performed at least at three levels.
➔If the observations are of same type, the data-level fusion it is an appropriate way to combine raw multisensory data for simplifies.



There are some automatic systems based on data fusion:
➔For emotion recognition, based on data collection and data classification received from sensors. They used feature level multisensory data fusion. The experimental part consisted in using of four channel physiological signals (electromyogram, skin conductivity, electrocardiogram, respiration changes) and measurement by synchronized time and unique dimension.
➔ For human activity recognition, based on accelerometers and gyroscopes which allow identification of body position in static and dynamic postures (movements).

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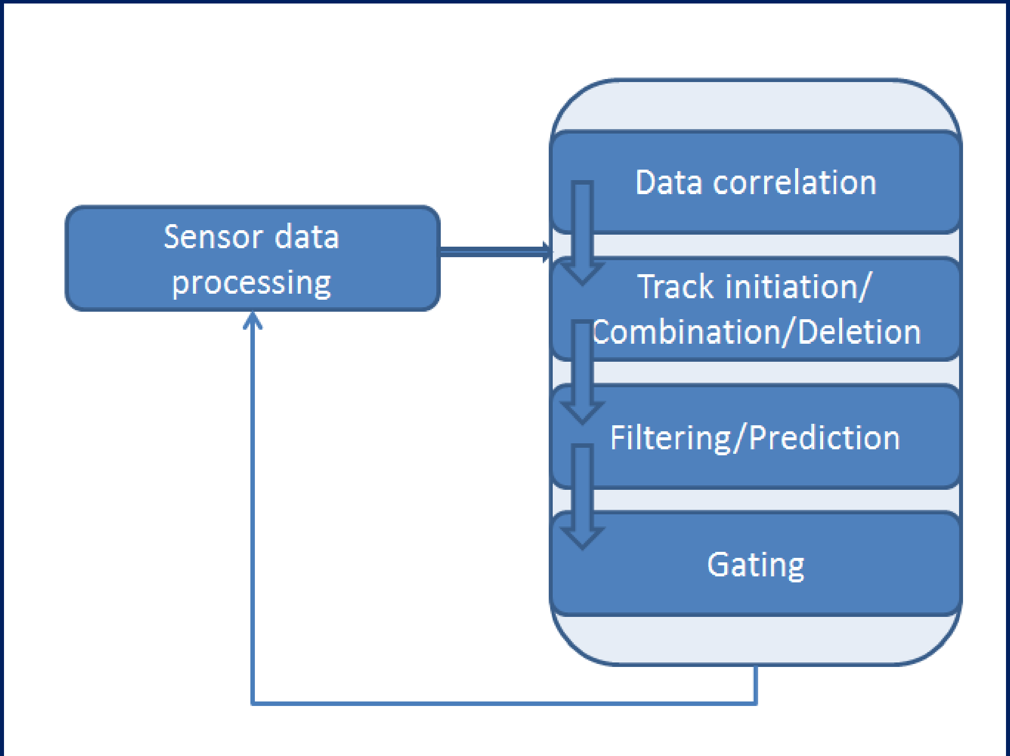
Sensor data processing

The optimized algorithm for sensor data tracking:

- extract the maximum information from the sensors;
- avoid making wrong and absurd conclusions based on aberrant values data;
- do not waste costly system resources (memory & energy).



For sensors we consider the mathematical function representation:

$$S(E, t) = \{V(t), e(t)\}$$

Where:

S- Function which maps the environment to numerical values V;

E-environment to measure the values V (temperature, pulse, breath rhythm and humidity);

t – time;

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➔Actual trends based on ubiquitous computing, pervasive computing and IoT, are to integrate the smart systems in any products which could provide portability (wearable electronics).
Today wearable electronics leads to integrating the electronic devices into textile surface by using different mechanical or physical/chemical procedures.

➔In case of the electronics integrated in textile the sensor nodes, their interfaces with the textile and the communication and power lines are single point failures.
The fault-tolerance and adaptability lead to system reconfiguration (remapping, code migration), which means high redundancy.

In case of integration of the electronic components (sensors, actuators and computational devices) on the textile surface (e-textile), may occurs <u>constraints related to system design which require high computational performance, low power consumption and fault tolerance.</u>

The physical nature of the e-textile (discrete model) and the faults developed by open and short circuit can disconnect/drain the battery, affecting both battery life and the performance of the e-textile, and finally can affect the accuracy signals from the e-textile

Usage of semiconductors integrated in textiles structures for the connections sensors/actuators - motherboard can affect signals data accuracy because of the yarns resistivity modifications with temperature variations, body thermal flow and due to the textile property to be good thermal conductor.

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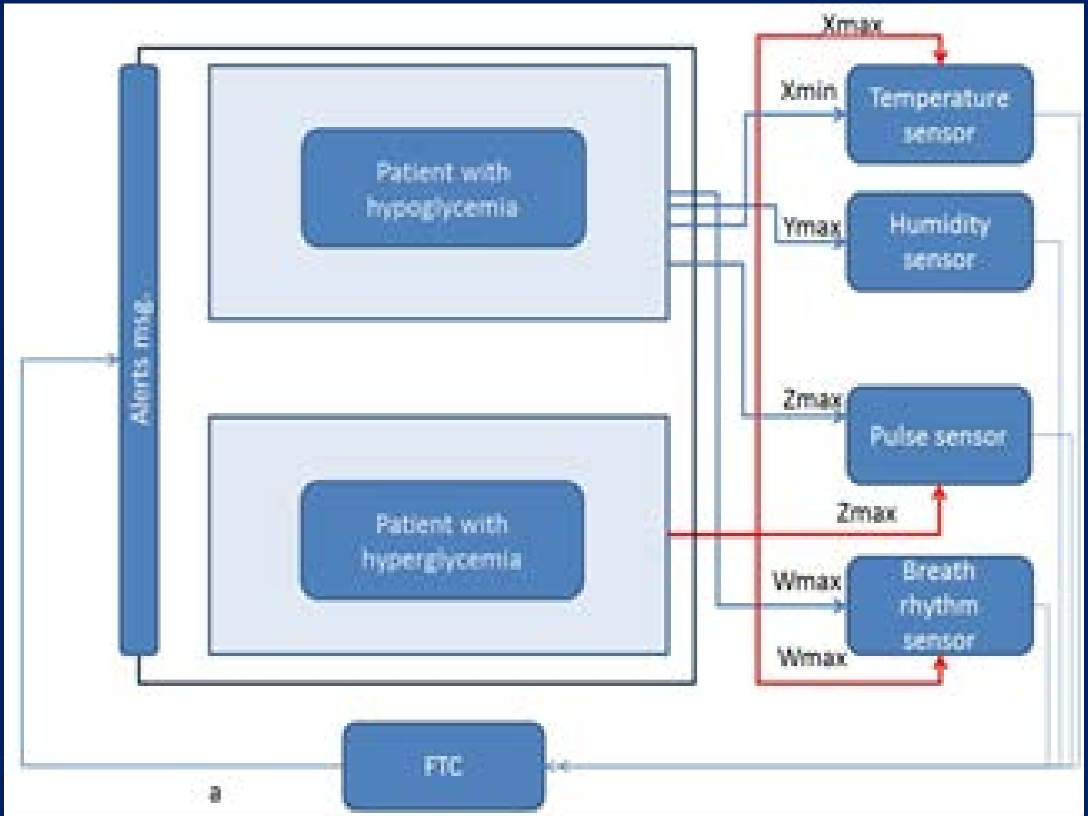
<u>The algorithm for FTC</u>
For t = 1, n do
Collect data: x, y, z, w
Verify output data and apply filters for data correction
Send alert message
End.



Fault tolerant control scheme

Biomedical critical signals (*pulse, temperature, humidity and breath rhythm*) ➔ FTC block ➔comparison ➔ optimal decision ➔ message alerts.
Sensors output may generate the error (*which can be considered like fault events*):
-partial/total output loss;
-abrupt/continuous switching between modes of functioning;
-the measurement noise can model nonlinear aberrations;

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CONCLUSIONS

Wearable sensors for healthcare monitoring should consider the:

-fault tolerance control implementation;

-multisensor data fusion (model control predictive algorithms ➔ optimal decisions);

-sensor data processing algorithm for reducing the noise and data discretization;

-data correlation for sensors values measured;

➔Wearable electronics integrated in textile experience a data losses and low accuracy signals due to the textile structure properties.

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Thank You For Your Attention !

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