Big data predictive analytics for bioheat transfer modeling

PhD. Student Aileni Raluca Maria[1],
Prof. Dr. Eng. Pasca Sever[1],
Prof. Dr. Eng. Strungaru Rodica
Poliethnica University of Bucharest, Faculty of Electronics, Telecommunication and Information Technology

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- **Human body temperature** = f (metabolic processes, absorption/dissipation in ambient environment);
- Human body function as an adjustable thermostat (36.2÷37.4ºC);
- Human body react to external environment (when parameters such as humidity or temperature varies) and to internal environment variations generated by several diseases);
- Human body temperature is different for body's parts

Human body temperature (T_B) may be measured by using:

➔**invasive method** based on thermocouples, thermistors or POF sensors ➔tissue temperature;

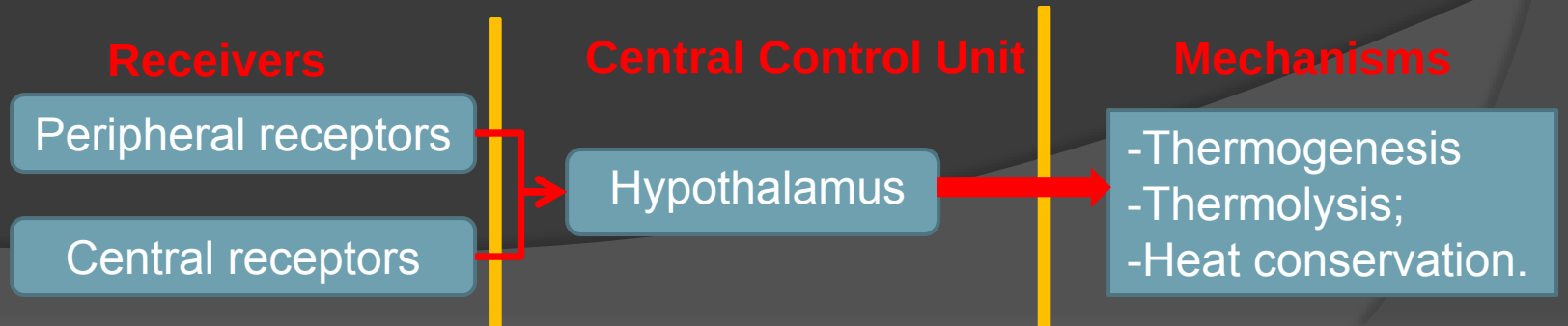
➔**noninvasive method** based thermometers, IR thermography, sensors ➔skin temperature.

Control system for human body is provided by hypothalamus:

➔thermogenesis (T_B < 36.2 º C)

➔thermolysis (T_B > 37.4 º C)

➔preserve heat (T_B < 36.2º C)



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Mathematical models used for bioheat transfer modeling:

- Pennes (1948) modeled blood effect as:

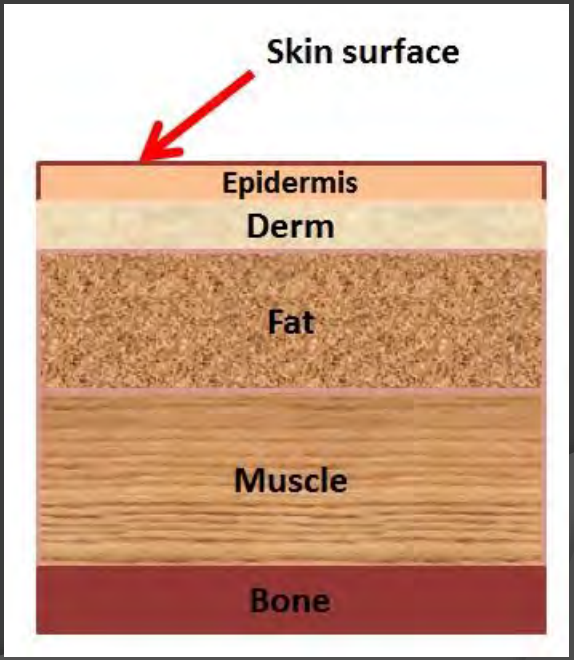
➔ an isotropic heat source

➔ is proportional to blood flow rate and the difference between the body core temperature and local tissue temperature.

➔ Used for decribing the influence of the blood flow for the tissues temperature:

$$\rho_{ti} C_{ti} \frac{\partial T_{ti}}{\partial T_t} = \nabla k_{ti} \nabla T_{ti} + \rho_{bl} C_{bl} W_{bl} (T_{art} - T_{ti}) + q_m$$

ρ_{ti}=tissue density;
C_{ti}=specific heat of tissue;
T_{ti} =temperature of tissue;
k_{ti} =thermal conductivity of tissue;
T_{art}=temperature of arterial blood;
q_m=metabolic heat ;
ρ_{bl} =blood density;
C_{bl}=temperature of arterial blood;
W_{bl}=perfusion rate of blood.



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- Between metabolic processes and heat behavior are some correlations (T.E. Cooper & G.J. Trezek)

-thermal conductivity of tissue:

$k = \rho x 10^{-3} (0.628\, f_{water} + 0.117\, f_{proteins} + 0.231\, f_{lipides})$ W/ m− K

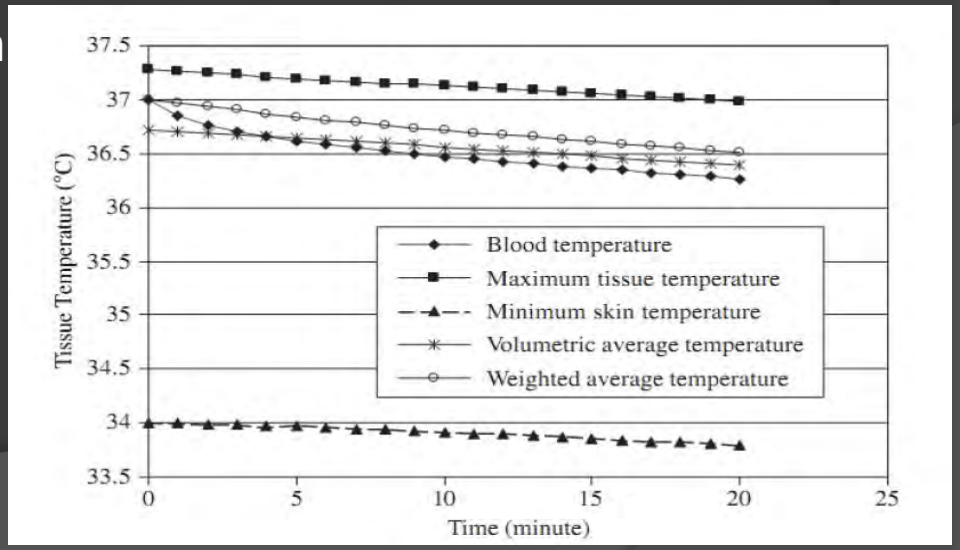
-specific heat of tissue:

$C_p = 4200 f_{water} + 1090 f_{proteins} + 2300 f_{lipides}$ J/kg-K

-tissue density:

$$\rho = \frac{1}{\frac{f_{water}}{1000} + \frac{f_{proteins}}{1540} + \frac{f_{lipides}}{815}} \quad kg/m^3$$

- Vascular model for heat transfer through tissues (Zhu- assumption that blood vessel are covered by tissues)



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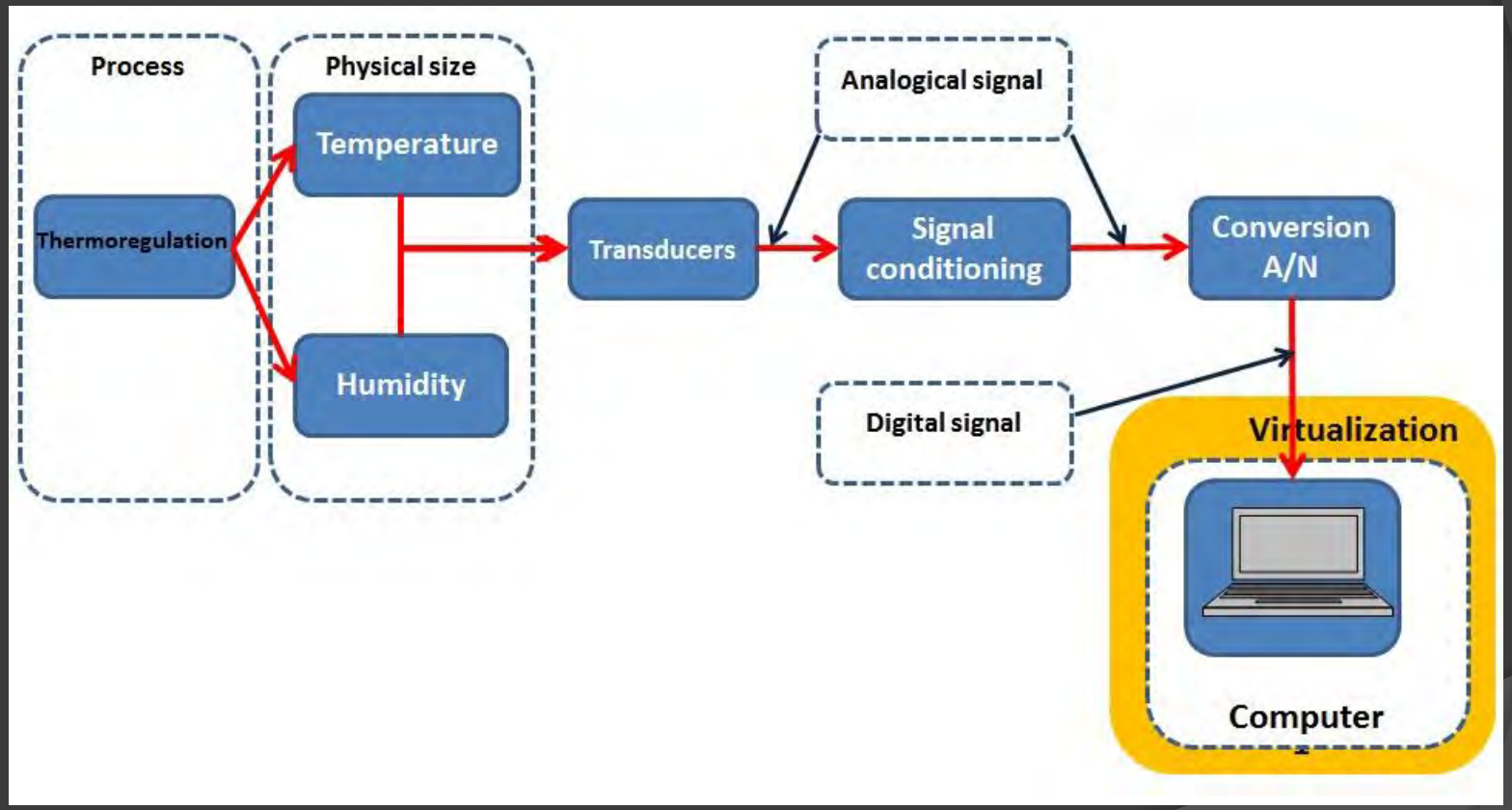
Thermoregulation process view and sensors monitoring:



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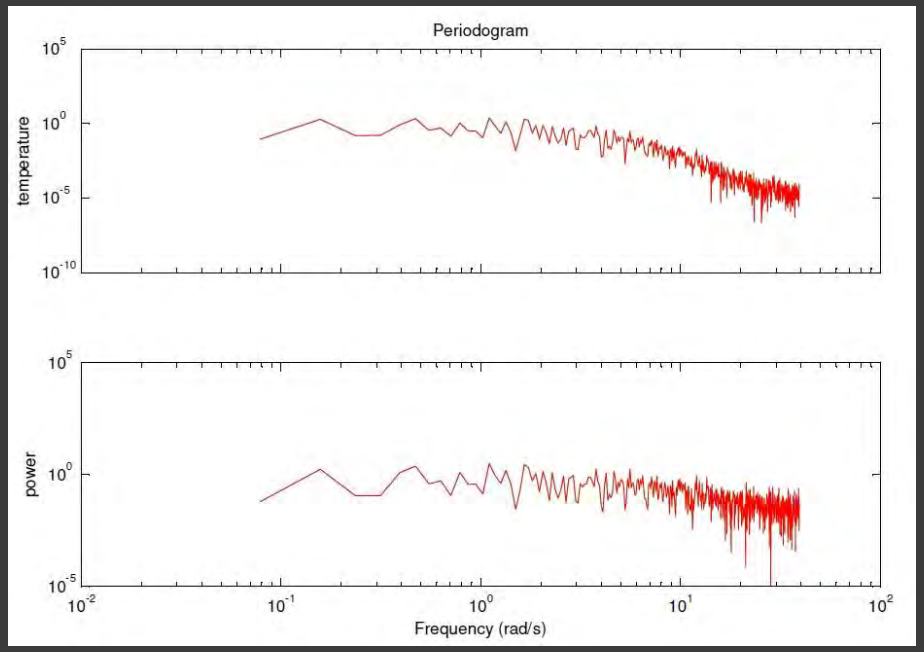

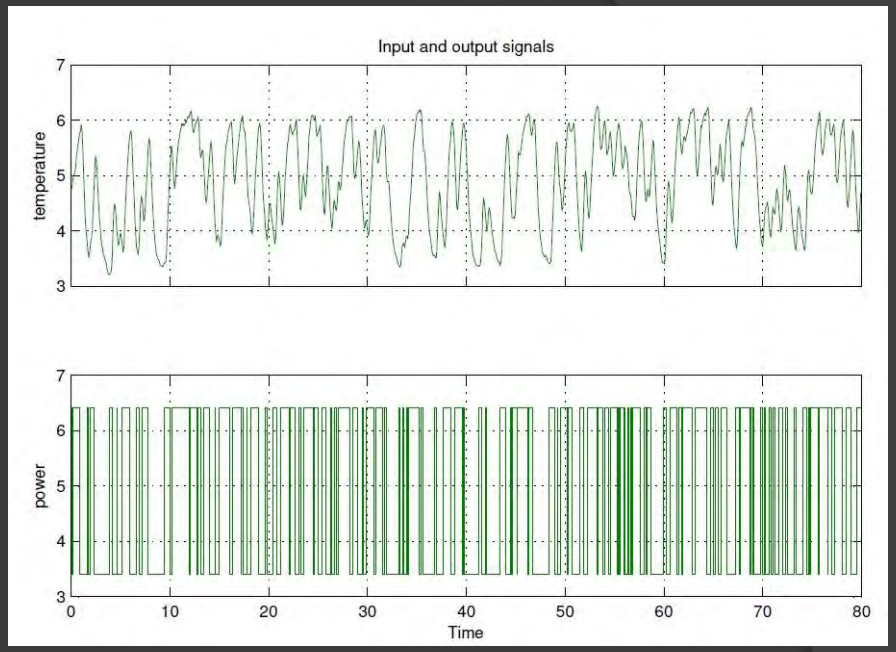

➔ Temperature sensors➔ continuous signal ➔ discrete time signal sampling (500 milliseconds)

➔ Sampling frequency: f_e=1/T =1/0.5 = 2Hz

! Inconvenient: sampling frequency doesn't offer significant results regarding thermo physiological parameters variation because many values are repeated;

Solution: reduction of the solutions interval by removing the repetitive values (Hadoop MapReduce framework)

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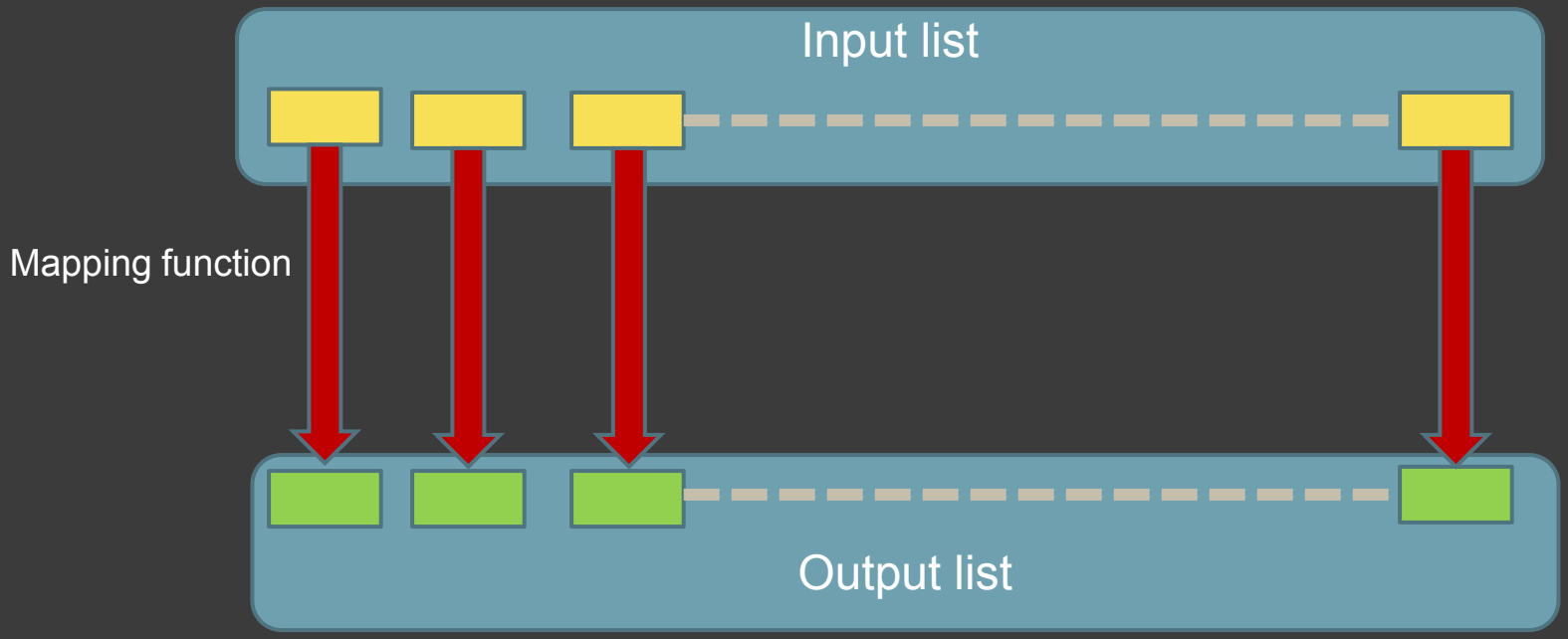

Input list = numerical values from sensors;
Output list = critical numerical value for sensors parameters

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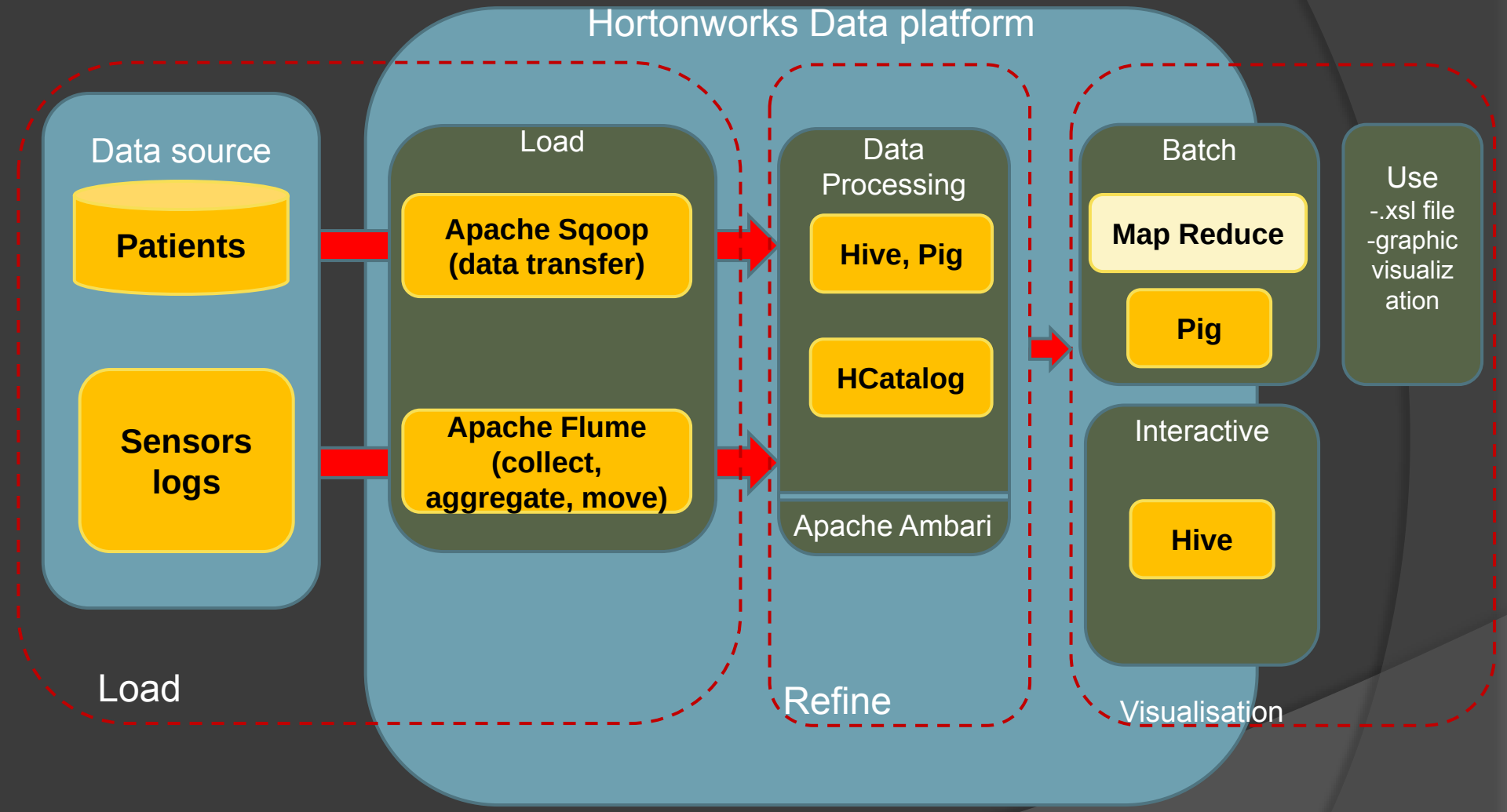

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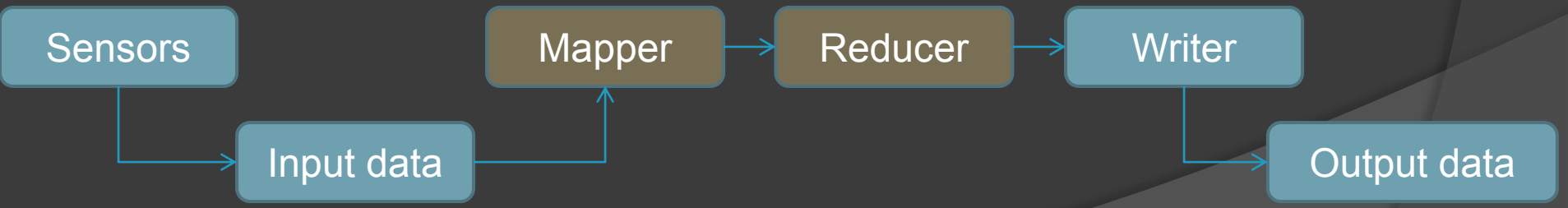
MapReduce:

- Set the the temperature limits:

```
INSERT INTO TABLE temperature
Select
*,
high_limit_temperature-actual_temperature as critical_temperature,
IF ((high_limit_temperature-actual_temperature)>1.2, ‘Low’,
IF ((actual_temperature-high_limit_temperature)>1, ‘High’)) AS temperature_limit
IF ((high_limit_temperature-actual_temperature)<1.2, ‘Normal’
IF ((high_limit_temperature-actual_temperature)<1, ‘Normal’)) AS temperature_normal
from temperature_data;
```



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Conclusions:

➔ temperature must be correlated with cardiovascular monitoring, in order to provide a real insight into the causes and effects arising from certain diseases.
➔Hadoop ➔rapid code programming and testing;
➔virtualization and data analytics for health predictive modeling;
➔possibility to storage data from high patients number;
➔possibility to create interactive data visualization;
➔graphical visualization for a patients group.

Thank you for your attention !