XI International University Conference „Engineer of XXI Century” – 10 December 2021

Approach to the development of a cyber-physical systems of medical and biological processes

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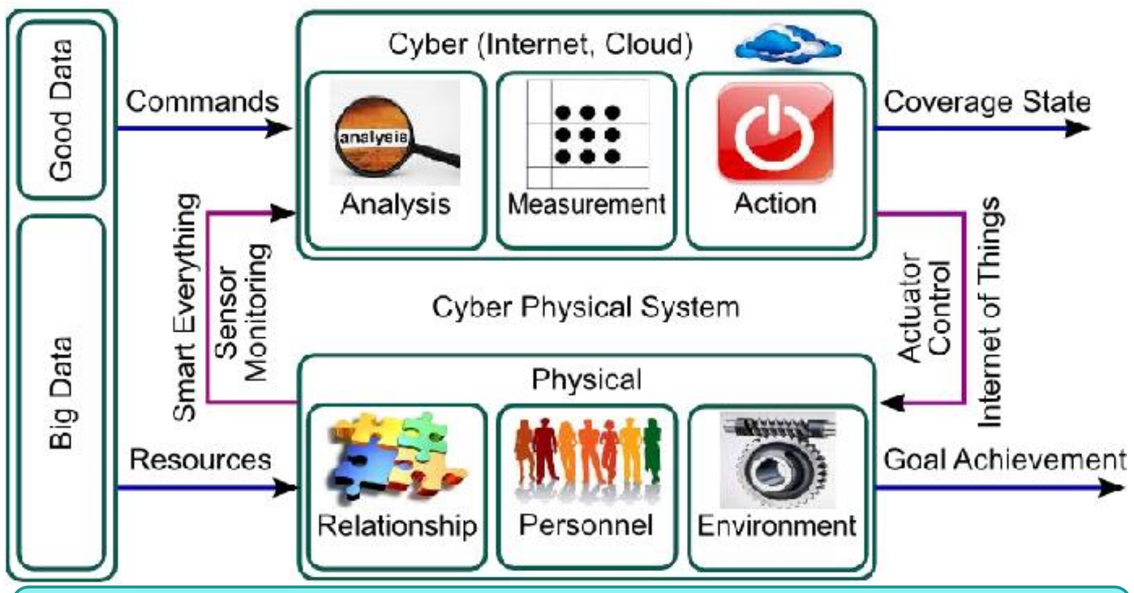
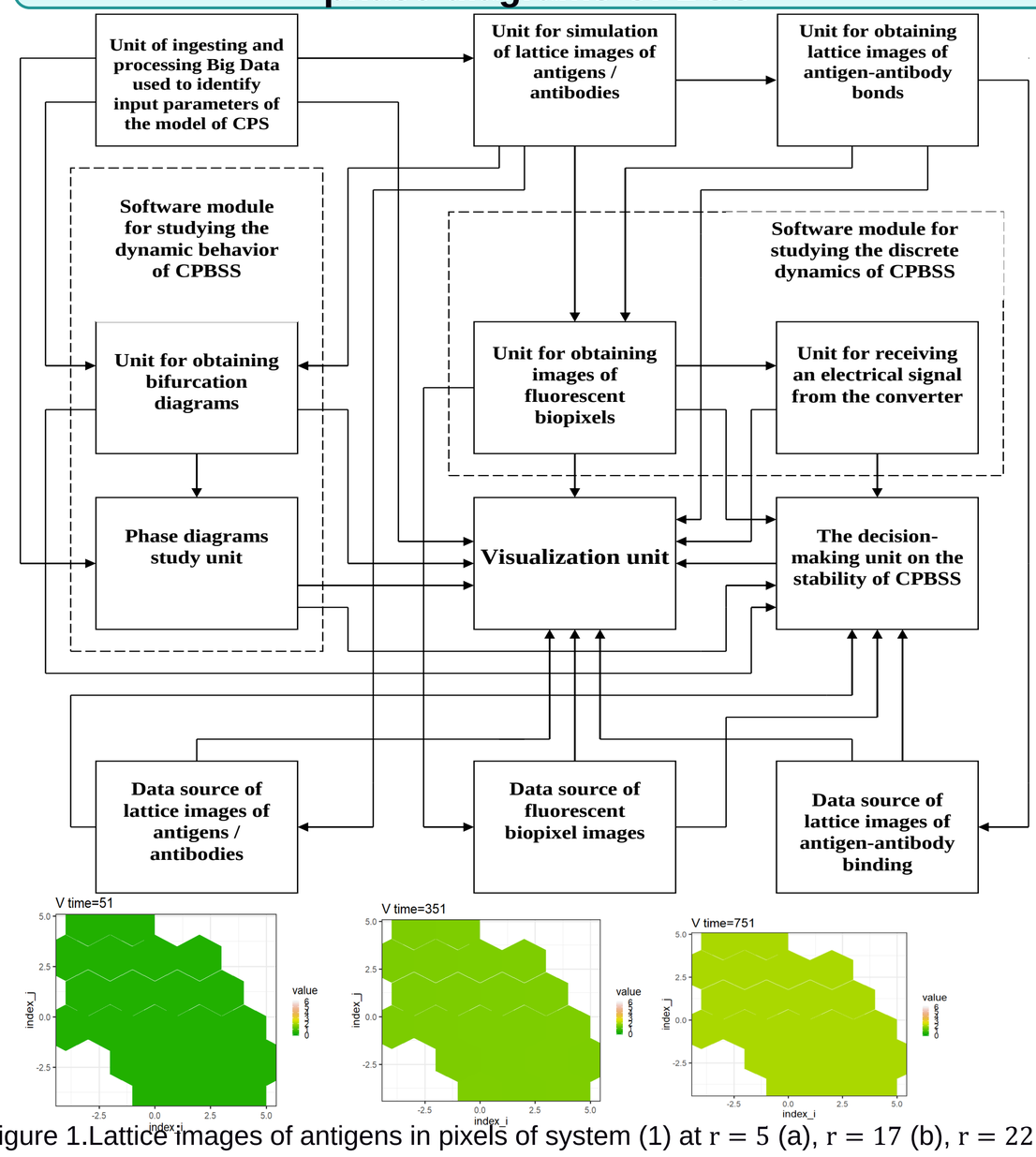
Abstract

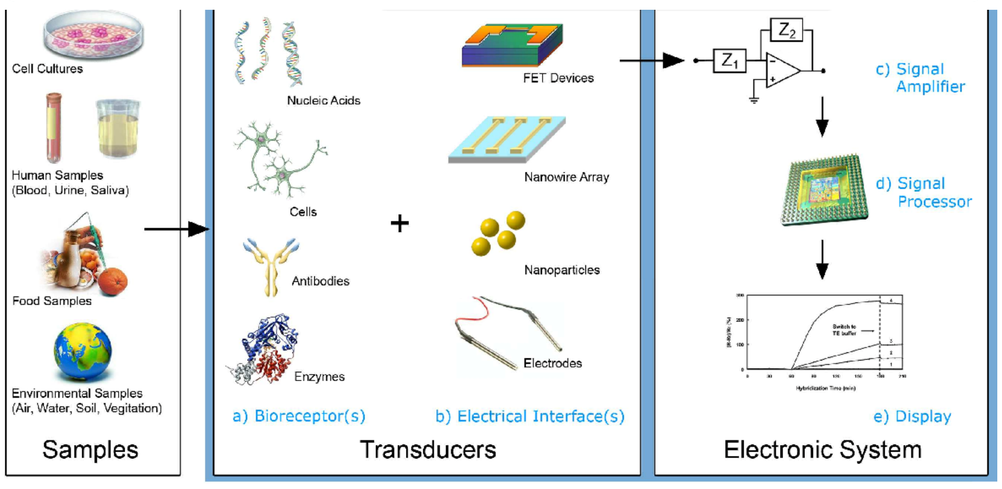
The work focuses on developing a Big Data system allowing us to process medical data intelligently, which are ingested from different sources and of various types. The work offers the mathematical description of the discrete population dynamics in combination with the dynamic logic of the studied models of the most advanced biosensors as biopixels arrays which are used at the analytics stage of scientific machine learning. The results of computer simulation of mathematical models of CPS of medical and biological processes in the form of images of antigens, antibodies, connections of antigens with antibodies, fluorescent pixels, and an electrical signal from the converter are obtained.



Block diagram of the software package for the study of phase diagrams CPBSS



Principle of cyber-physical biosensor systems



Mathematical model of biosensor on hexagonal lattice using lattice difference equations with time delay

In order to simulate the dynamic logic of an intelligent Big Data system for investigation the stability of CPS of medical and biological processes, we use the syntax proposed by A. Platzer for the general CPS. The CPS uses the Hybrid Programming Language, which has more features than differential equations. Consider the dynamic logical simulation of intelligent Big Data system for investigation the stability of CPS of medical and biological processes on the example of a mathematical model of biosensor on hexagonal lattice using lattice difference equations with delay. The first level of HP is a dynamic program that is defined by the following grammar

$$a ::= V_{i,j,k}(n+1) = V_{i,j,k}(n)exp\{\beta - \Upsilon F_{i,j,k}(n-r) - \delta_v V_{i,j,k}(n-r)\} + \hat{S}\{V_{i,j,k}(n)\},$$

$$F_{i,j,k}(n+1) = F_{i,j,k}(n)exp\{-\mu_f + \eta\Upsilon V_{i,j,k}(n-r) - \delta_f F_{i,j,k}(n)\}\&\Phi_t \quad (1)$$

where Φ_t is an evolutionary domain constraint in the form of a formula for the logic of the first order of real arithmetic

$$\Phi_t \stackrel{\text{def}}{=} V^{min} \le V_{i,j,k}(n) \le V^{max}$$
$$\wedge F^{min} \le F_{i,j,k}(n) \le F^{max} \wedge i,j,k = \overline{-N,N} \wedge n > 0, i+j+k = 0 \quad (2)$$

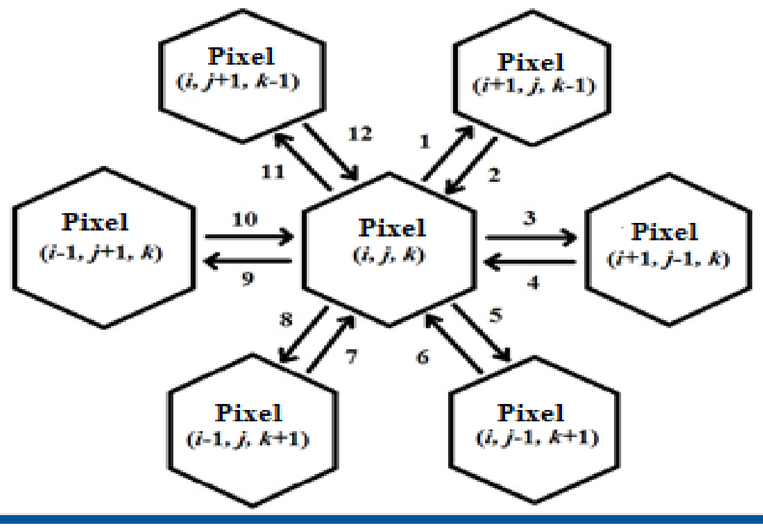


Figure 1.Lattice images of antigens in pixels of system (1) at r = 5 (a), r = 17 (b), r = 22 (c)

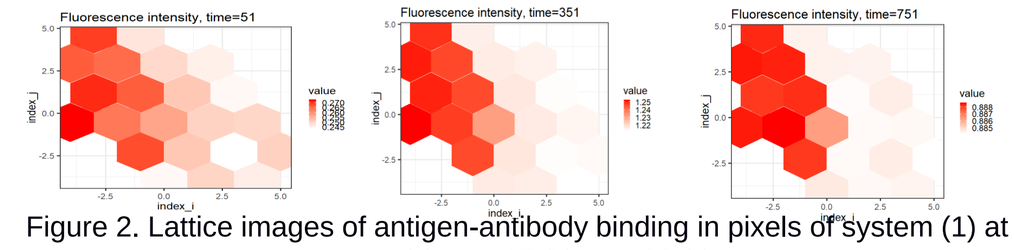


Figure 2. Lattice images of antigen-antibody binding in pixels of system (1) at r = 5 (a), r = 17 (b), r = 22 (c)

Conclusion

In the work the general scheme of the cyber-physical sensor system was extended to the usage of Big Data. The basic model has been modified to take into account the features of biosensors. Lattice images in biopixels are modified according to the laws of discrete dynamics. The developed models take into account the interaction of biopixels with each other by antigen diffusion.

Ministerstwo Edukacji i Nauki

Dofinansowano z programu „Doskonała nauka” Ministra Edukacji i Nauki