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# PARAMETER ESTIMATION OF BIOSENSOR SYSTEM USING GENETIC ALGORITHM

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**ABSTRACT**
In the paper is proposed a method for parameter estimation of the biosensor on the base of accuracy factor by means of the genetic algorithm. The proposed method determining all diffusions *(d,l,$D_S$ )* and kinetics *($V_m$, $K_M$ )* parameters on the base of metrological (γ, $S_o$) parameters of the biosensor. Appropriate parameters of the biosensor can be determined in advance and that way to construct the biosensor with desired accuracy.
**Key words:** amperometric biosensor, genetic algorithm, parameter estimation.

## 1. INTRODUCTION

Biosensors systems are very complex devices. They consist of an integrated receptor-transducer device, which is capable of providing selective quantitative or semi-quantitative analytical information using a biological recognition element. Amperometric biosensors based on oxidize enzymes are very popular [1,2]. During the enzymatic bioconversion oxygen is consumed (for co-substrate mode). The efficient reduction of oxygen at the surface of the cathode causes the oxygen concentration there to be near zero. In amperometric biosensors the output current produced from the electrochemical reduction of oxygen at the working electrode is measured as a function of the applied potential.

## 2. GENETIC ALGORITHM MODEL AND OBJECTIVE FUNCTION DEFINITION

We will examine tissue amperometric biosensor. For example is used a constructed biosensor for measuring concentration of catechol [3]. Active membrane is from spinach tissue. The investigated biosensor system is co-substrate sensitive. The measured substrate catechol is with concentration – *So,* co-substrate is oxygen with concentration *Co*. For the medial transducer is used oxygen electrode which mark the decreasing of concentration of oxygen throws the enzyme reaction in the active membrane.

The assessment of the quality of the biosensor system in steady state regime is done by the $\Phi_\gamma$ – accuracy factor [4].

$$\Phi_\gamma = \frac{\left(\frac{V_m}{K_M}\right)\left(\frac{l^2}{D_S}\right)(0{,}5 + d/l)}{\gamma S_o + 1} \qquad (1)$$

where
*Vm* – maximal velocity of enzyme reaction [mM/s];
$K_M$ - reaction rate constant for substrate [mM];
*l* – active membrane thickness [m];
$D_S$ – diffusion coefficient for substrate [m²/s];
*d* – dialyze membrane thickness [m];
$\gamma = \Delta / So$ – relative error; $S(0) = \Delta$ - concentration of substrate at the electrode surface;

It is seen that accuracy factor unify the all diffusions *(d,l,$D_S$ )*, kinetics *($V_m$, $K_M$ )* and metrological (γ, $S_o$) parameters of the biosensor.

In the paper we propose a method for parameter estimation of the biosensor on the base of accuracy factor by means of the genetic algorithm.

Genetic algorithms (GA) [5] belong to optimization methods for solving sets of non-linear equations. They use objective functions based on some criterion which is most often the calculated error. Sometimes the reciprocal value of this criterion, called fitness function, is used. GA are based on

natural selection and natural genetics. Using random numbers, they do not need a good initial guess for unknowns. The mechanism of the most elementary GA consists of copying strings, random number generation and swapping parts of strings. It uses the following operators – reproduction, crossover and mutation [5].

Reproduction is the process in which individual strings are selected according to their fitness. Fitness is determined by calculating how well each string fits an objective function. Strings that fit the objective better have a higher probability of contributing to off springs in the next generation.

Crossover is step in GA in which each pair mutually interchanges a randomly selected portion of bits to produce variety. Thus, new strings are generated in the new population.

After crossover the entire population passes through another step in GA called mutation. During mutation randomly selected bits of a randomly selected string are changed from 1 to 0 and vice versa to prevent the GA from losing useful information.

The substantial advantages of genetic algorithms over other optimization methods are:

- GA are able to find the fitness function's global minimum instead of a local minimum. This is due to the fact that they simultaneously explore many points in the search space. Covering the whole search space, they are less likely to stop at a local minimum.
- GA does not require problem-specific auxiliary knowledge such as derivatives of the function.
- The initial guesses for estimated parameters do not need to be close to the actual values.

The criterion for selecting the best individuals in the genetic algorithm is the objective function. An adequately - chosen objective function guarantees that the next generation is usually closer to the solution of the problem. The objective function $F_{obj}$ used in the present study is the relative error between accuracy factor calculated with the help of GA $\Phi_{\gamma_c}$ and accuracy factor for the given biosensor system $\Phi_{\gamma_d}$ with known parameters

$$F_{obj} = \frac{\Phi_{\gamma_c}}{\Phi_{\gamma_d}} - 1, \qquad (2)$$

The aim of GA is to minimize the error of the objective function defined by (2) and on that base find the values of the five parameters of the biosensor, namely – $Vm$, $K_M$ , $l$ , $D_S$ , $d$ . For the desired /with known parameters / biosensor system we set the measurement range of the biosensor $So_H = 2mM$ and rellative error $\gamma = 0,01$.

## 3. RESULTS AND DISCUSSIONS

The genetic algorithm parameters are presented in Table 1.

First we calculate the accuracy factor for the given and known biosensor system with the known parameters:

$Vm$ =0,18 mM/s; $K_M$ = 0,45mM; $l$= $70\mu m$;
$D_S = 1,24.10^{-10}$ m²/s; $d$ = 25$\mu m$ and it is $\Phi_{\gamma_d}$ =13,17

for the relative error $\gamma = 0,01$ and $So_H = 2mM$.

GA stops at Fobj = 1,01.10 $^{-13}$, for the current tolerance on fitness function is 8,12.10 $^{-11}$ is less than given in options - 1,00.10$^{-10}$

At the fig.1 is given the plot of evaluation process. The optimized parameters finded by GA are

$Vm$ =0,29 mM/s; $K_M$ = 0,35mM; $l$= $64,1\mu m$; $D_S$ = $1,97.10^{-10}$ m²/s; $d$ = 20,1$\mu m$

For the other biosensor system with desired accuracy factor smaller then given $\Phi_{\gamma_d}$ = 5, or bigger then given $\Phi_{\gamma_d}$ = 10 or 15, results are shown in the table 2. The reseived results are with very big accurasy about 8,12.10 $^{-11}$ – to 1,19.10$^{-17}$.

Table 1. Genetic algorithm parameters

| | |
|---|---|
| Population size | 10 |
| Generations | 20 |
| MigrationFraction | 0.75 |
| MigrationInterval | 2 |
| Crossover fraction | 0,2 |

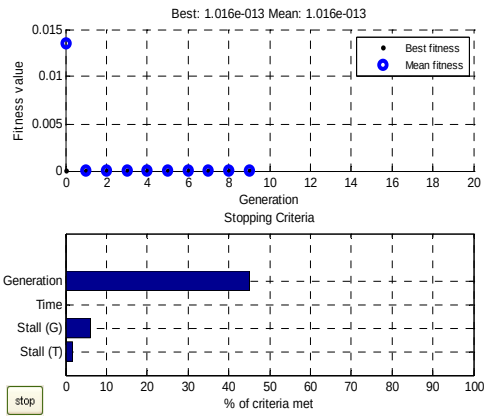


Fig.1. Evaluation process of GA

Table 2. Measured (known) and estimated from the GA parameters of the biosensor system

| Parameter | known value | Estimated from GA | | | |
|---|---|---|---|---|---|
| | | $\Phi_{\gamma d}$ = 13,17 | $\Phi_{\gamma d}$ = 5 | $\Phi_{\gamma d}$ = 10 | $\Phi_{\gamma d}$ = 15 |
| *Vm* | 0.18 | 0.30 | 0.30 | 0.29 | 0.29 |
| $K_M$ | 0.45 | 0.59 | 0.60 | 0.34 | 0.35 |
| *l* | $70.10^{-6}$ | $66,50.10^{-6}$ | $51,23.10^{-6}$ | $51,5.10^{-6}$ | $61.10^{-6}$ |
| $D_S$ | 1.24 | 1.25 | 1.98 | 1.99 | 1.99 |
| *d* | $25.10^{-6}$ | $16,75.10^{-6}$ | $13,15.10^{-6}$ | $19,99.10^{-6}$ | $27,5.10^{-6}$ |

The analysis of the results in Table 2 and figures from 2 to 6, shows that if we want to construct biosensor system with smaller accuracy factor for example $\Phi_{\gamma d}$ = 5, we must to reduce active membrane thicknes *l* and increase the reaction rate constant *Vm*. If we want to construct biosensor system with bigger accuracy factor for example $\Phi_{\gamma d}$ = 20, we must to reduce reaction rate constant *Km* and maximal velocity *Vm*.

For the investigated area $\Phi_{\gamma d}$ (from 5 to 20) we can say that active membrane thickness *l* has maximum for the biosensor with accuracy factor $\Phi_{\gamma d}$ = 13,17, diffusion coefficient *Ds* has minimum for the biosensor with accuracy factor $\Phi_{\gamma d}$ = 13,17, maximal velocity *Vm* is minimum for the biosensor with accuracy factor $\Phi_{\gamma d}$ = 20.

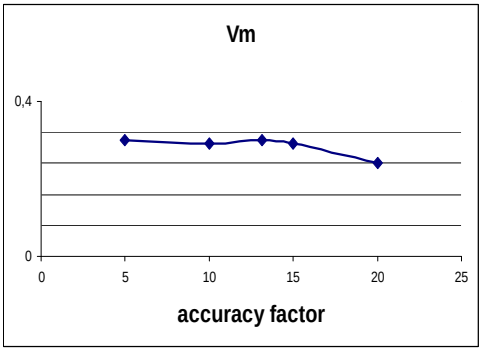


Fig.2 Alteration of maximal velocity Vm

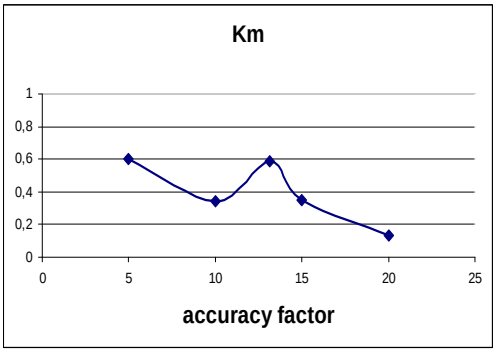


Fig.3. Alteration of reaction rate constant

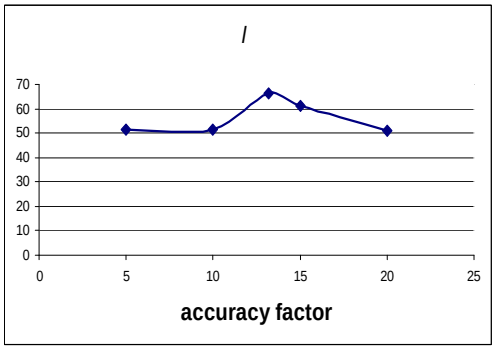


Fig.4 Alteration of membrane thickness

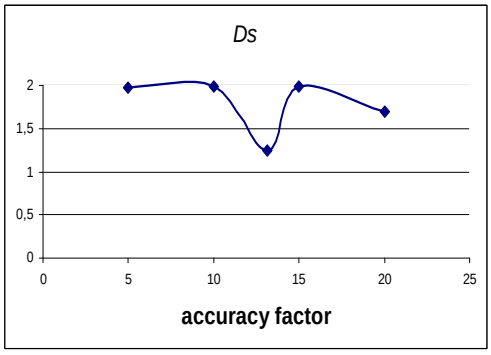


Fig.5. Alteration of diffusion coefficient

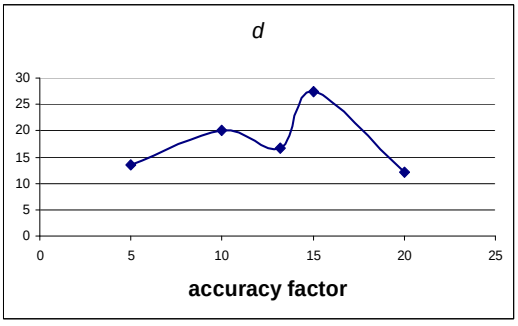


Fig.6. Alteration of dialyze membrane thickness

The convergence history of GA is given in Fig. 1. There is a fast and smooth convergence of the objective function. The objective function value at which the genetic algorithm terminates is Fobj = 1,01.10 $^{-13}$.

## 4. CONCLUSION

The proposed method for parameter estimation of the biosensor on the base of accuracy factor by means of the genetic algorithms shows that appropriate parameters of the biosensor can be determined in advance and that way receive the biosensor with desired accuracy. Method defined all diffusions $(d,l,D_S)$ and kinetics $(V_m, K_M)$ parameters on the base of metrological ($\gamma$, $S_o$) parameters of the biosensor.

## REFERENCES

[1] *Climent P. V, M. L. M. Serralheiro, and M. J. F. Rebelo. Development of a new amperometric biosensor based on polyphenoloxidase and polyethersulphone membrane Pure Appl. Chem., Vol. 73, No. 12, pp. 1993–1999, 2001*

[2] *Lourenço R.J.M., M.L.M. Serralheiro, M.J.F. Rebeloa. Development of a New Amperometric Biosensor for Lactose Determination Portugaliae Electrochimica Acta 21, 171-177, 2003*

[3] *Rangelova V., Al. Neykov et all. Tissue biosensors for catechol 12th Scientific Symposium "Metrology & Metrology Assurance'2002, 18-21 Sept., Sozopol, 228-232,2002*

[4] *Katsarova P. Generalized criterion for assessment of quality and its place in diagnostics of biosensors, Journal of the Technical University at Plovdiv, Vol. 13 (5), 111-116, 2006*

[5] *R. Haupt and S. Haupt. Practical genetic algorithms. Wiley & Sons, 2004*

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