**Estimation of parameters for solar cells with S–shaped current–voltage characteristics using meta–heuristic algorithms**

Oleg Olikh

*Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska Street, Kyiv, 01601, Ukraine*

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S1. Fitting results (lines) for the simulated current-voltage characteristic (symbols). The values *I*01= 1.6⋅10-6 mA, *n*1= 1.92, *R*p1 = 190 Ω, *I*02 = 0.16 mA, *n*2= 1.92, *R*p2 =190 Ω, *R*s = 45 Ω, *I*ph = 8 mA were assumed under simulation. | | |

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  | |
| Fig.S2. The results of algorithm comparison in *I*01 (a), *n*1 (b), *R*p1 (c), *I*02 (d), *n*2 (e), *R*p2 (f), *R*s (g), *I*ph (h) evaluation, RMSPE (i), and Comp (j) parameters by Friedman, Friedman Aligned, and Quade tests in the single-IV case. The colored hexagon indicates that the adjusted *p*-value, which tests the hypothesis that an algorithm in a row outperforms an algorithm in a column, is not greater than *plim* = 0.1. The solid fill signifies that every post-hoc procedure resulted in *p* < *plim*; the patterned fill indicates that only specific post-hoc procedures achieved this outcome. The correspondence between the color and position of the hexagon to a test as well as the fill pattern to procedures are shown in a legend at the bottom of the figure. | |

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| Fig.S3. The results of multiple comparisons in *I*01 (a), *n*1 (b), *R*p1 (c), *I*02 (d), *n*2 (e), *R*p2 (f), *R*s (g), *I*ph (h) evaluation, RMSPE (i), and Comp (j) parameters among all algorithms in the single--IV case. The colored cylinder indicates that the adjusted *p*-value, which tests the control algorithm outperforms the comparison algorithm, is not greater than *p*lim =0.1. The correspondence between the color of the cylinder to a post-hoc procedure is shown in the figure legend. | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S4. Fitting results (lines) for the simulated current-voltage characteristic (symbols). The parameters values from Sec.2.2.2 were assumed under simulation. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S5. Comparison of *I*01 value estimation by different algorithms on the IV curve set. Circles represent the *I*01 values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S6. Comparison of *n*1 value estimation by different algorithms on the IV curve set. Circles represent the *n*1 values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S7. Comparison of *R*p1 value estimation by different algorithms on the IV curve set. Circles represent the *R*p1 values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S8. Comparison of *I*02 value estimation by different algorithms on the IV curve set. Circles represent the *I*02 values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S9. Comparison of *n*2 value estimation by different algorithms on the IV curve set. Circles represent the *n*2 values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S10. Comparison of *R*p2 value estimation by different algorithms on the IV curve set. Circles represent the *R*p2 values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S11. Comparison of *R*s value estimation by different algorithms on the IV curve set. Circles represent the *R*s values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S12. Comparison of *I*ph value estimation by different algorithms on the IV curve set. Circles represent the *I*ph values, which have been used in IV curve simulations, squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| Fig.S13. Comparison of RMSPE value for different algorithms, applied to the IV curve set. Squares represent the median values, and stars represent the mean values. The colored regions correspond to the IQR. The lines only serve as guide to the eye. | | |