**An Embedded Gene Selection Method Using Knockoffs Optimizing Neural Network**

Juncheng Guo1,2,3, Min Jin4, Yuanyuan Chen4, Jianxiao Liu1,4,\*

1Hubei Key Laboratory of Agricultural Bioinformatics, College of Informatics, Huazhong Agricultural University, Wuhan, 430070

2Institute of Information Engineering, Chinese Academy of Sciences, Beijing 100093, China

3School of Cyber Security, University of Chinese Academy of Sciences, Beijing 100093, China

4National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan, 430070

E-mail addresses:

Juncheng Guo: yuexiaozhuoke@gmail.com (J. Guo)

Min Jin: 834245464@qq.com (M. Jin)

Yuanyuan Chen: yychentamu@163.com (Y. Chen)

Jianxiao Liu: liujianxiao321@163.com (J. Liu)

\*Correspondence: Jianxiao Liu ([liujianxiao321@163.com](mailto:liujianxiao321@163.com))

The file includes seven figures (Figure 1 – Figure 7) and seven tables (Table 1 –Table 7). All the data is available at http://122.205.95.139/Knockoffs-NN/Dataset.rar. All the source code is available at http://122.205.95.139/Knockoffs-NN/Knockoffs-NN.rar.

## Figures

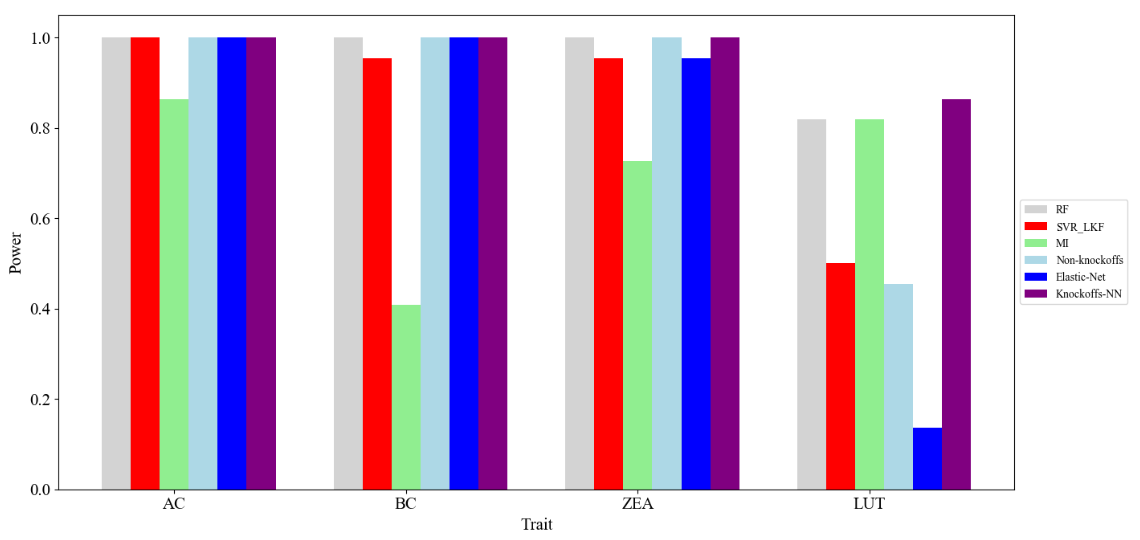


Figure 1. Result of gene *crtRB1*(GRMZM2G152135) for maize carotenoids

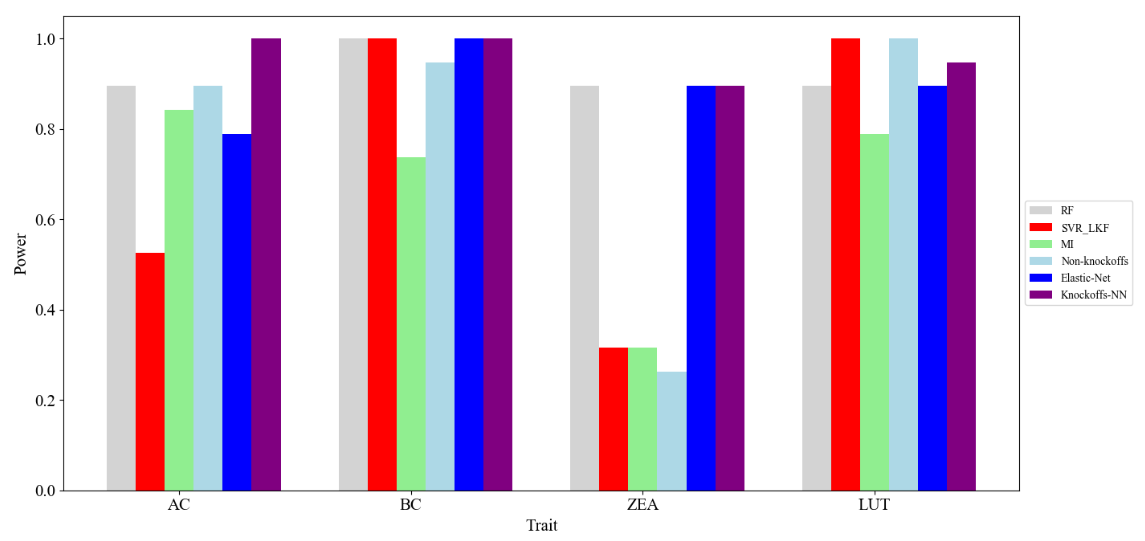


Figure 2. Result of gene *lcyE*(GRMZM2G012966) for maize carotenoids

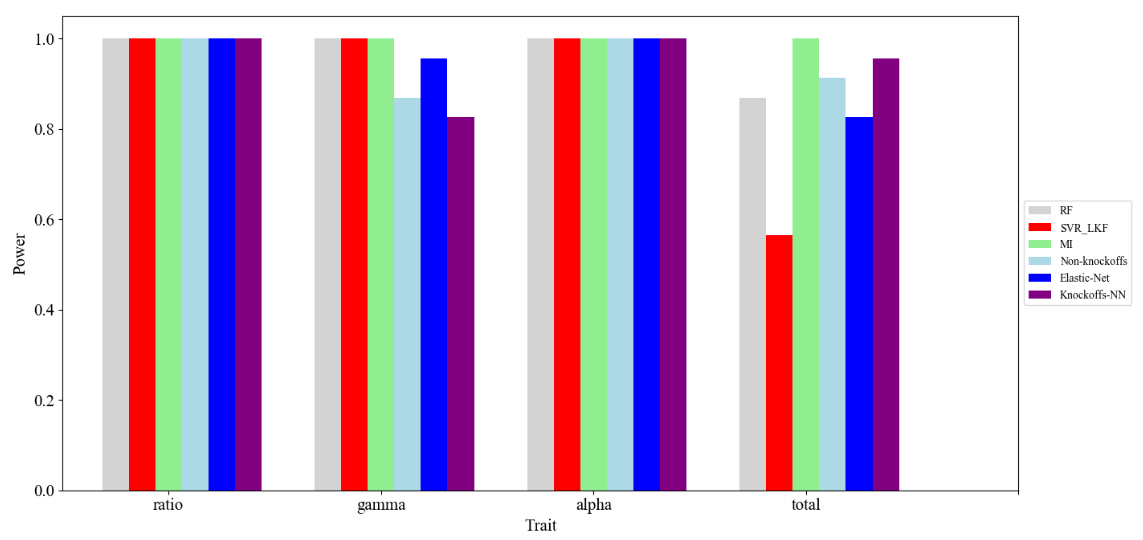


Figure 3. Result of gene *VTE4*(GRMZM2G035213) for maize tocopherol

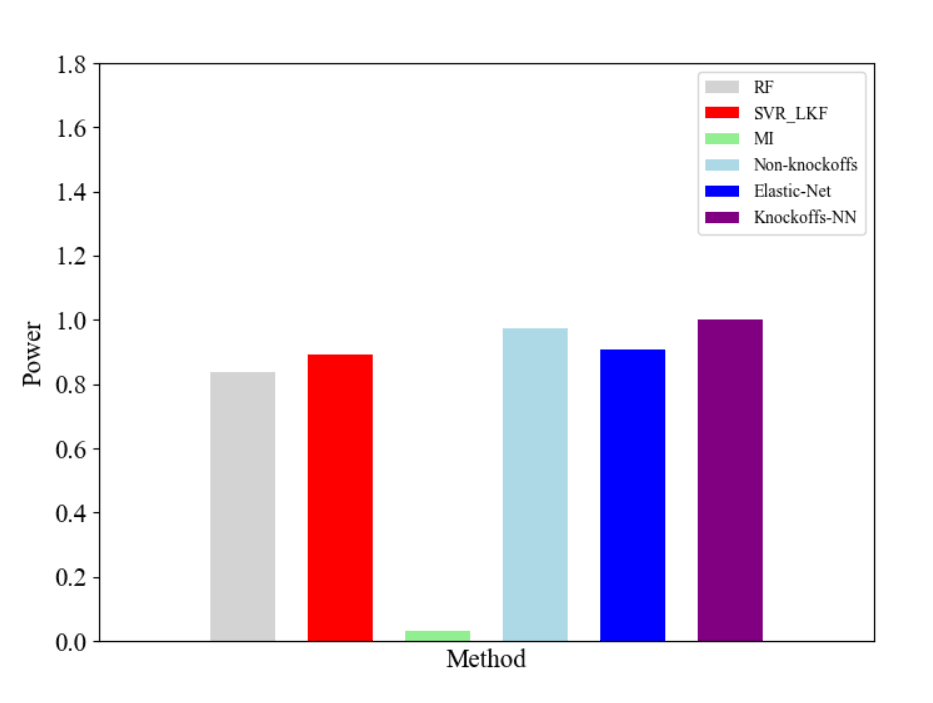


Figure 4. Result of gene *ZmGOL* (GRMZM5G872256) for maize raffinose

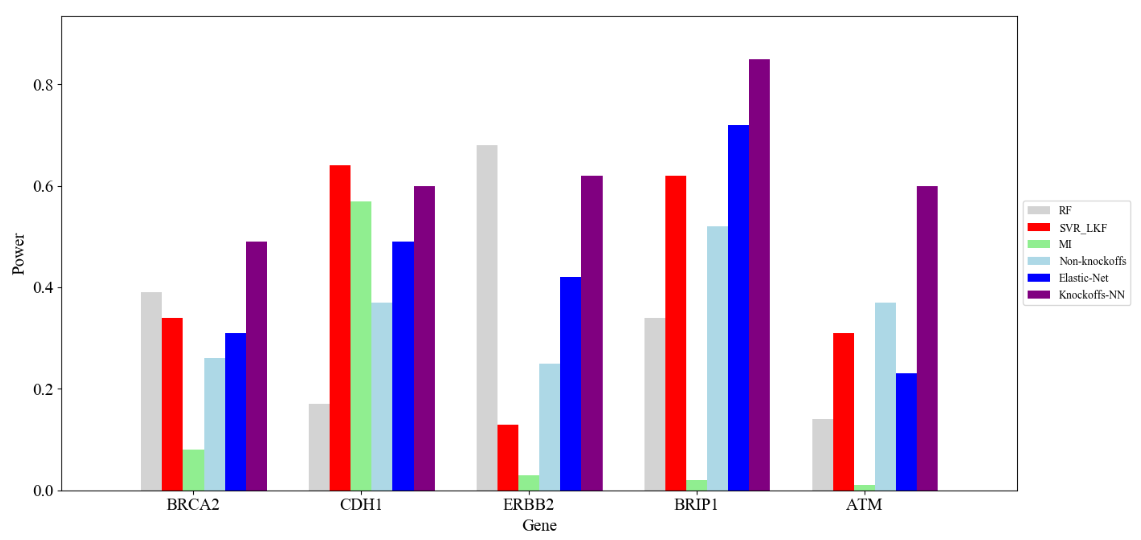


Figure 5. Results of human breast cancer dataset



Figure 6. The framework of our method

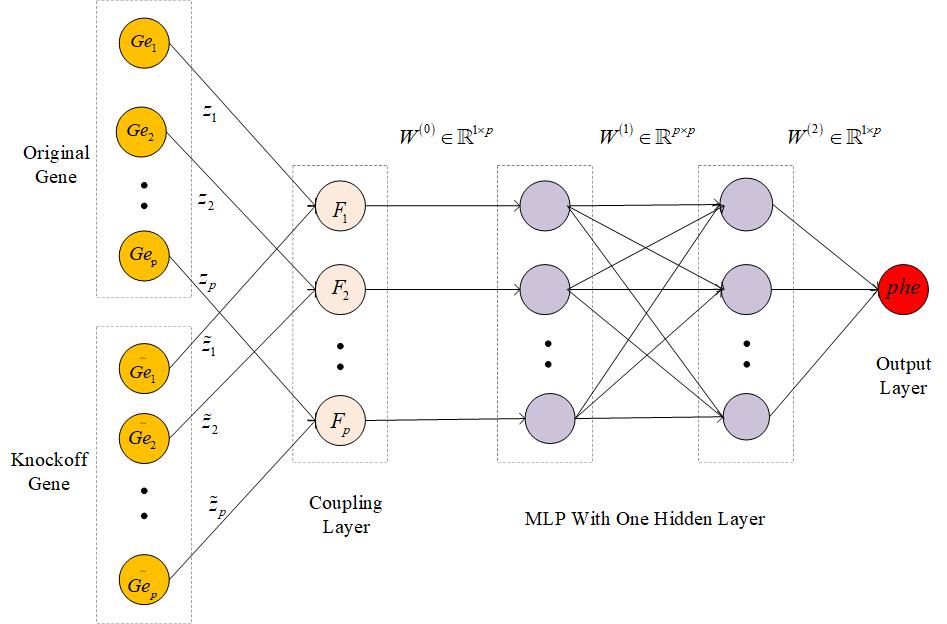


Figure 7. The gene selection framework of knockoff optimizing neural network

## Tables

Table 1. Parameters setting in the experiment

|  |  |
| --- | --- |
| Parameter setting | Value |
| Activation function | ReLU |
| Regularization | L1 |
| Loss function | Mean square error (MSE) |
| Optimization | Batch gradient descent and Adam (recommend mini-batch for large samples) |
| Number of hidden layer | 1 |
| Number of hidden layer neurons (genes) | Number of genes |
| Learning rate | 0.0001 |

Table 2. The ranking of *crtRB1*(GRMZM2G152135) about different phenotypes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Methods  Traits | RF | SVR\_LKF | MI | Elastic-Net | Non-Knockoffs | Knockoffs-NN |
| *AC* | 1 | 1 | 4 | 1 | 1 | 1 |
| *BC* | 1 | 2 | 14 | 1 | 1 | 1 |
| *ZEA* | 1 | 2 | 7 | 2 | 1 | 1 |
| *LUT* | 5 | 12 | 5 | 20 | 13 | 4 |

Table 3. The ranking of *lcyE*(GRMZM2G012966) about different phenotypes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Methods  Traits | RF | SVR\_LKF | MI | Elastic-Net | Non-Knockoffs | Knockoffs-NN |
| *AC* | 3 | 10 | 4 | 5 | 3 | 1 |
| *BC* | 1 | 1 | 6 | 1 | 2 | 1 |
| *ZEA* | 3 | 14 | 1 | 3 | 15 | 3 |
| *LUT* | 3 | 1 | 5 | 3 | 1 | 2 |

Table 4. The ranking of *VTE4*(GRMZM2G035213) about different phenotypes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Methods  Traits | RF | SVR\_LKF | MI | Elastic-Net | Non-Knockoffs | Knockoffs-NN |
| *ratio* | 1 | 1 | 1 | 1 | 1 | 1 |
| *gamma* | 1 | 1 | 1 | 2 | 4 | 5 |
| *alpha* | 1 | 1 | 1 | 1 | 1 | 1 |
| *total* | 4 | 11 | 1 | 5 | 3 | 2 |

Table 5. The ranking of *ZmGOL*(GRMZM5G872256) about maize raffinose

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Methods  Trait | RF | SVR\_LKF | MI | Elastic-Net | Non-Knockoffs | Knockoffs-NN |
| M71 | 36 | 24 | 209 | 21 | 7 | 1 |

Table 6. The results of *ZmGOL*(GRMZM5G872256) about top-5 genes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Methods  Number | RF | SVR\_LKF | MI | Non-  Knockoffs | Elsatic-  Net | Knockoffs-NN |
| 1 | GRMZM2G092174  (0.048) | GRMZM2G005984  (0.396) | GRMZM2G043295  (0.126) | GRMZM2G121360  (0.529) | GRMZM2G121360  (0.420) | GRMZM5G872256  (0.00358520178299) |
| 2 | GRMZM2G060842  (0.033) | GRMZM2G022686  (0.221) | GRMZM2G092174  (0.108) | GRMZM5G875954  (0.411) | GRMZM2G102382  (0.377 | GRMZM5G877547  (0.00290219524756) |
| 3 | GRMZM2G129815  (0.027) | GRMZM2G121360  (0.205) | GRMZM2G129815  (0.090) | GRMZM2G134107  (0.390) | GRMZM2G005984  (0.376) | GRMZM2G134471  (0.0028602059655) |
| 4 | GRMZM2G022398  (0.022) | GRMZM2G040268  (0.164) | GRMZM2G121360  (0.088) | GRMZM5G850567  (0.323) | GRMZM2G134107  (0.359) | GRMZM2G700004  (0.00263825481301) |
| 5 | GRMZM5G875954  (0.022) | GRMZM2G181551  (0.161) | GRMZM2G317262  (0.087) | GRMZM5G872256  (0.304) | GRMZM2G415117  (0.320) | GRMZM5G875954  (0.00259085517355) |

Table 7. The gene ranking of human breast cancer dataset

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Methods  Ranking | RF | SVR\_LKF | MI | Elastic-Net | Non-Knockoffs | Knockoffs-NN |
| RCA2 | 62 | 67 | 62 | 70 | 75 | 52 |
| *DH1* | 84 | 37 | 84 | 52 | 64 | 41 |
| *RBB2* | 33 | 88 | 33 | 59 | 76 | 39 |
| *BRIP1* | 67 | 39 | 67 | 29 | 49 | 16 |
| *ATM* | 87 | 70 | 87 | 78 | 64 | 41 |