Laboratory Note

Genetic Epistasis
III - Assessing Algorithm BOOST

LN-3-2014

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May 2014

Abstract

In this lab note, the algorithm BOOST is discussed. Its main features are transforming the data representation of genotypes into a Boolean type and making logic operations and pruning statistically irrelevant epistatic interactions. The results show a higher Power in main effect than epistasis detection, but has a much higher Type I Error Rate than epistasis detection. This is also true for full effect detection. The scalability of the algorithm is very good, revealing only a slight increase in the use of resources and running time with the increase of population size.

1 Introduction

BOOST (BOolean Operation-based Screening and Testing) [WYY+10] transforms the data representation into a Boolean type, making logic operations more efficient and prunes insignificant epistatic interactions using an upper bound based on the likelihood ratio test statistic. BOOST works in two stages:

- **Stage 1: Screening** All pairwise interactions are evaluated using the contingency tables collected by Boolean operations, removing interactions that fail to meet a predefined threshold. The evaluation of the interactions at this stage is represented by Kullback-Leibler divergence $D = N \cdot D_{KL}(\hat{\pi}||\hat{\rho})$ where $\hat{\pi}$ represent the joint distribution by the full logistic regression model $M_S = \beta_0 + \beta_i^{x_1} + \beta_j^{x_2} + \beta_{ij}^{x_1 x_2}$, and $\hat{\rho}$ is the approximate joint distribution under the main logistic regression model $M_H = \beta_0 + \beta_i^{x_1} + \beta_j^{x_2}$ using the method "Kirkwood superposition approximation".
- **Stage 2: Testing** Two statistic tests are used: likelihood ratio test, fitting the log-linear models M_H and M_S, and χ^2 with four degrees of freedom. The p value is adjusted by a Bonferroni correction.

1.1 Input files

The input data files contain a file with the SNP and phenotype information, and a file containing the names of all data set files. In the data files, the first column corresponds to the phenotype taking its value in 0,1. From the second to the last column corresponds to the SNP, taking values in 0,1,2.

1.2 Output files

The output consists of two files, the interaction results, consisting of all SNP pairs with a χ^2 result above 30 and contains the following columns:

- **Index** : number of interaction. Begins with 0
- **SNP1** : first SNP in the interaction. Numeration begins with 0.
- **SNP2** : second SNP in the interaction. Numeration begins with 0.
- **SinglelocusAssoc1** : value of the marginal effect for the first associated SNP.

- **SinglelocusAssoc2** : value of the marginal effect for the second associated SNP.
- **InteractionBOOST** : The statistical value of BOOST from the χ^2 test.
- **InteractionPLINK** : value obtained by using the statistic of PLINK.

The second file contains the marginal effect value for every SNP. The file contains two columns:

- **SNPindex** : number of the SNP.
- **Single-locusTestValue** : value of the χ^2 test.

2 Experimental Settings

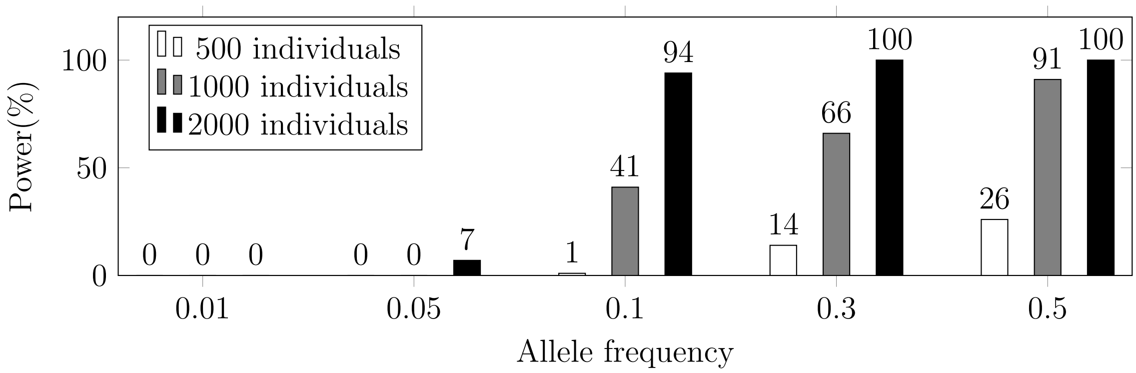
The datasets used in the experiments are characterized in Lab Note 1. The computer used for this experiments used the 64-bit Ubuntu 13.10 operating system, with an Intel(R) Core(TM)2 Quad6 CPU Q6600 2.40GHz processor and 8,00 GB of RAM memory.
BOOST is a C program. There are no settings for BOOST.

3 Results

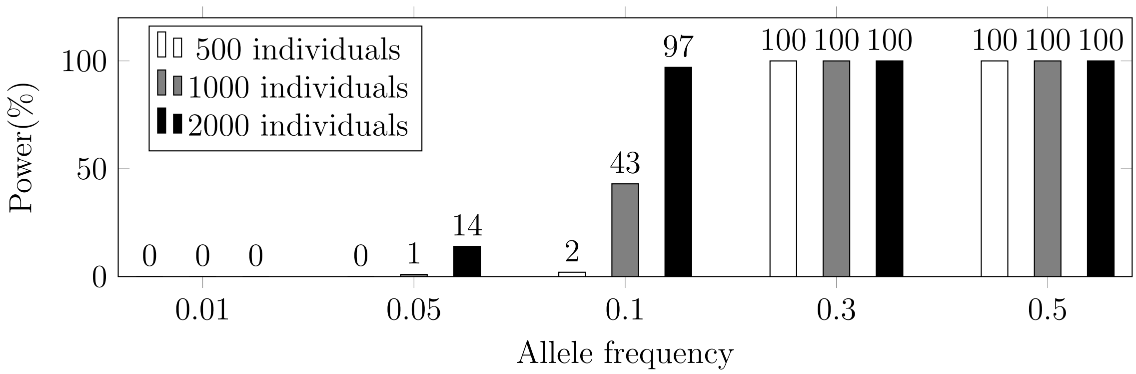
The Power displayed in epistasis (b) is inferior to the Power detected by main effects (a) and the best results were obtained by full effect detection (c) in almost all configurations. In epistasis detection, Figure 1 shows an increase of Power with population size in nearly all allele frequencies. The increase of allele frequency also increases the Power.

In Figure 2 shows a varying cpu usage (b) with a very slight increase in running time (a), and memory usage (c)This increase is not significant, which reveals a good scalability.

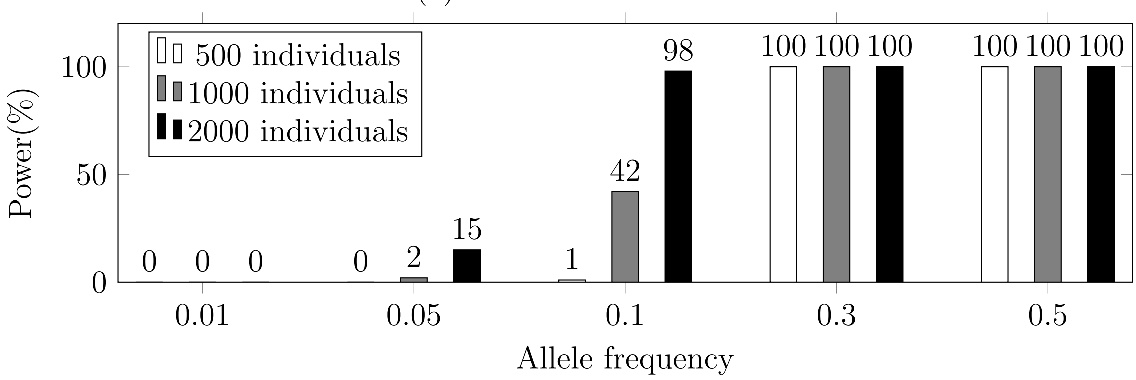
The Type I Error Rate shows a maximum value of 21% for epistasis detection, but is 100% in the data sets with the highest population size and allele frequency, for main effect and full effect. Most of the type 1 errors in epistasis are below 10% and therefore there is a bigger difference between Power and type 1 errors in epistasis detection. For main effect and full effect, there is an increase in Type 1 Error Rate with data set size and minor allele



(a) Epistasis

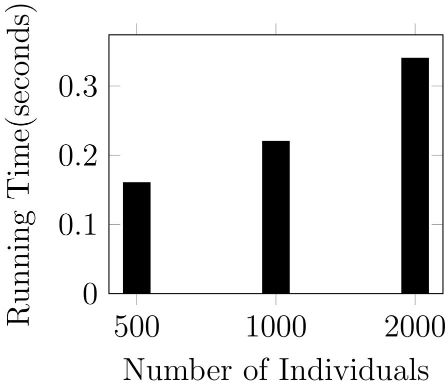


(b) Main Effect

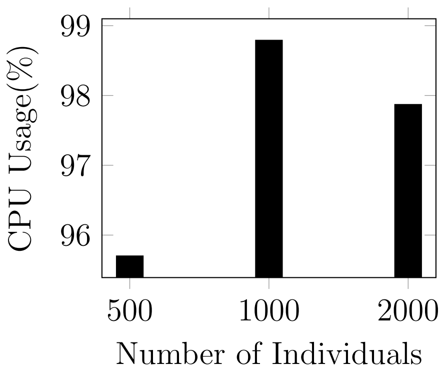


(c) Full Effect

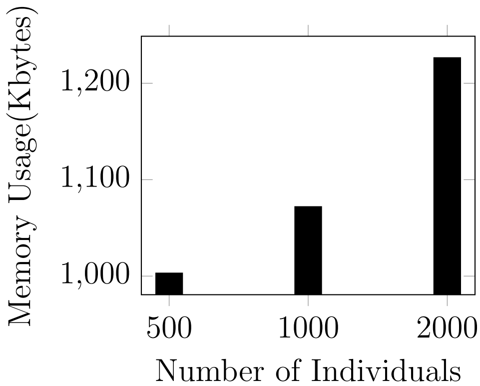
Figure 1: Power by allele frequency. For each frequency, three sizes of data sets were used to measure the Power, with odds ratio of 2.0 and prevalence of 0.02. The Power is measured by the amount of data sets where the ground truth was amongst the most relevant results, out of all 100 data sets. (b), (a), and (c) represent main effect, epistatic and main effect + epistatic interactions.



(a) Average running time.



(b) Average CPU usage.

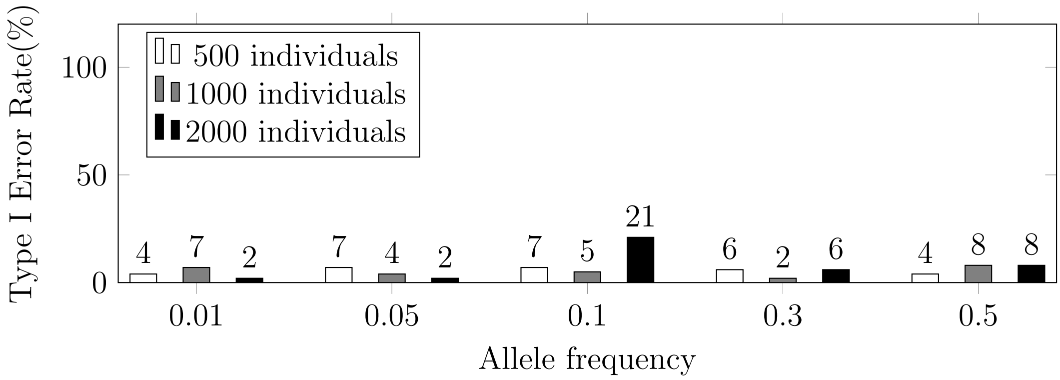


(c) Average memory usage.

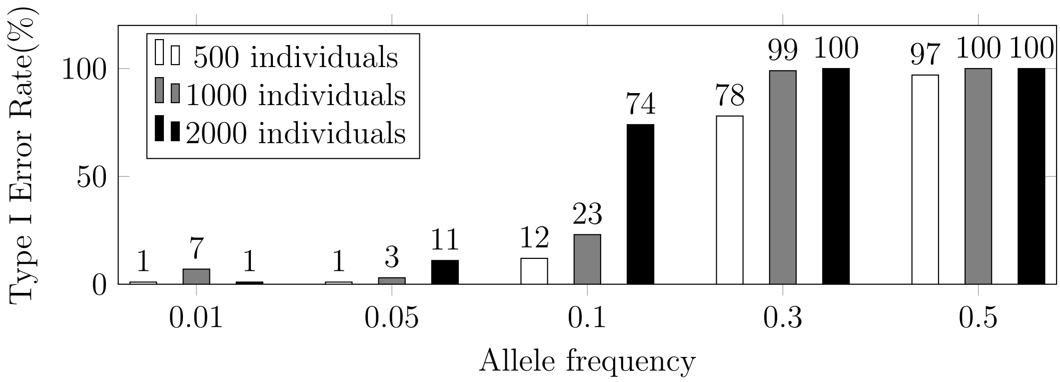
Figure 2: Comparison of scalability measures between different sized data sets. The data sets have a minor allele frequency is 0.5, 2.0 odds ratio, 0.02 prevalence and use the full effect disease model.

frequency.

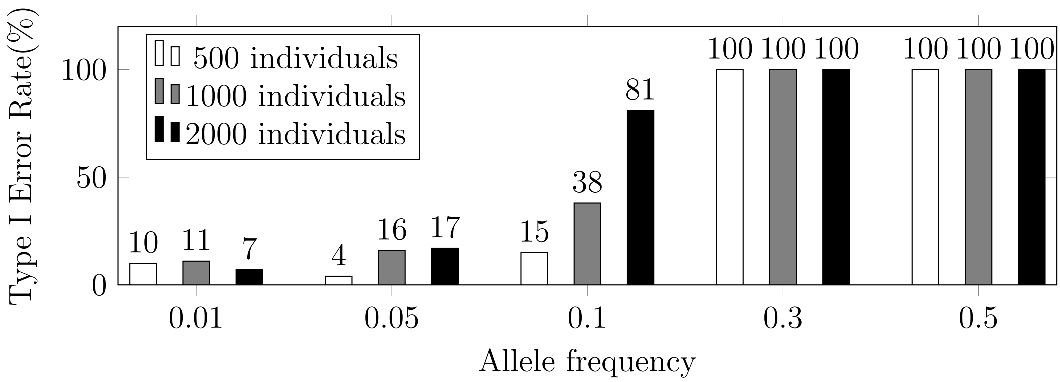
The Power distribution by population 4 and by odds ratio 5 show a big increase with higher population sizes and odds ratios. The prevalence result reveal very similar values for both prevalences , and the distribution by allele frequency 7 increases sligthly for 0.05 minor allele frequency and increases greatly in 0.1 minor allele frequency, reaching 100% for higher allele frequencies.



(a) Epistasis



(b) Main Effect



(c) Full Effect

Figure 3: Type I Error Rate by allele frequency. For each frequency, three sizes of data sets were used to measure the Power, with odds ratio of 2.0 and prevalence of 0.02. The Type I Error Rate is measured by the amount of data sets where the false positives were amongst the most relevant results, out of all 100 data sets.. (a), (b), and (c) represent epistatic, main effect, and main effect + epistatic interactions.

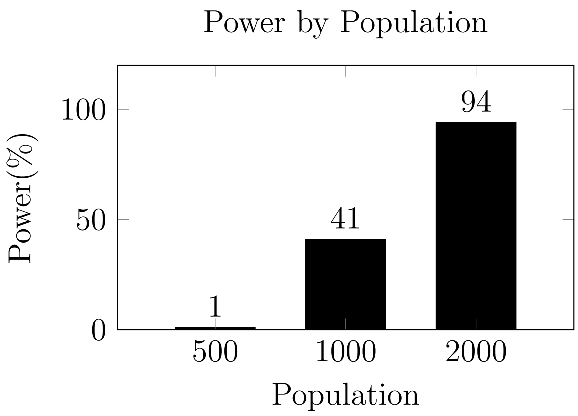
4 Summary

BOOST is an exhaustive algorithm that converts the data into a binary format and prunes irrelevant interactions by the contingency tables collected by Boolean operations. The results show a very good scalability, with a slight but irrelevant increase in running time, memory usage and cpu usage. The relation between Power and Type I Error Rates has a bigger difference in epistasis detection, but the overall Power is lower than main effect and full effect.

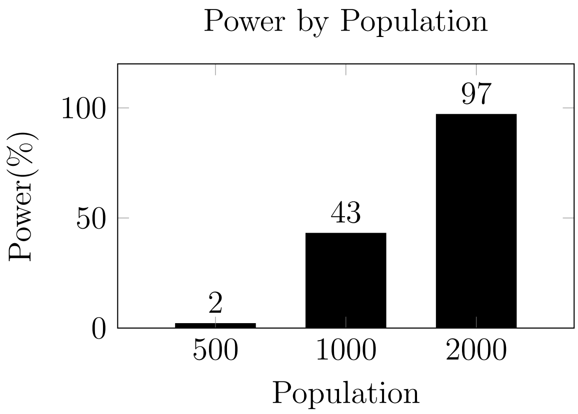
References

[WYY+10] Xiang Wan, Can Yang, Qiang Yang, Hong Xue, Xiaodan Fan, Nelson L S Tang, and Weichuan Yu. BOOST: A fast approach to detecting gene-gene interactions in genome-wide case-control studies. *American journal of human genetics*, 87:325–340, 2010.

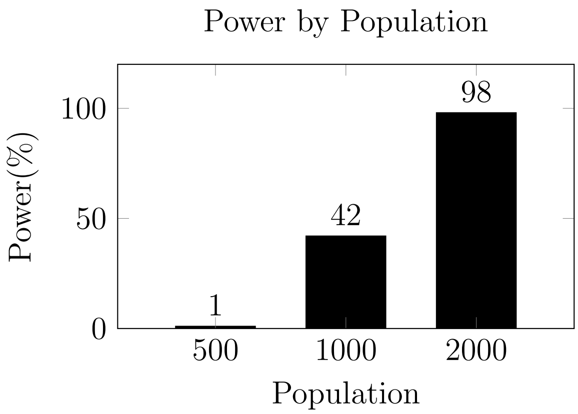
A Bar Graphs



(a) Epistasis

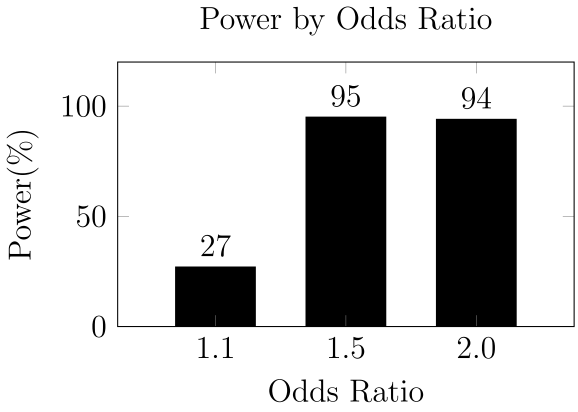


(b) Main Effect

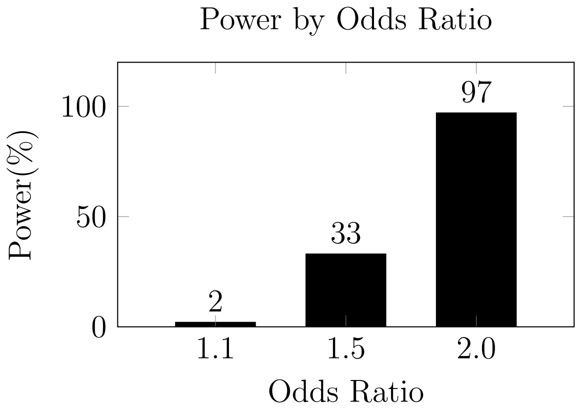


(c) Full Effect

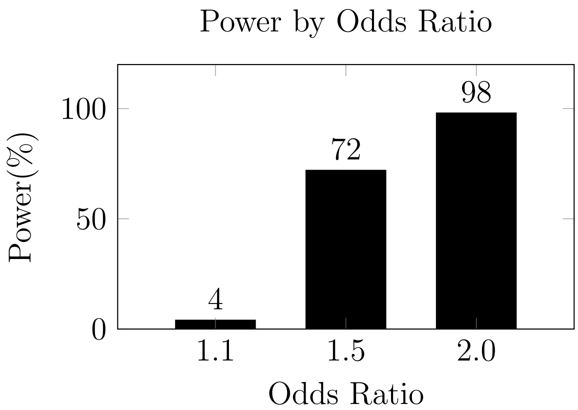
Figure 4: Distribution of the Power by population for all disease models. The allele frequency is 0.1, the odds ratio is 2.0, and the prevalence is 0.02.



(a) Epistasis

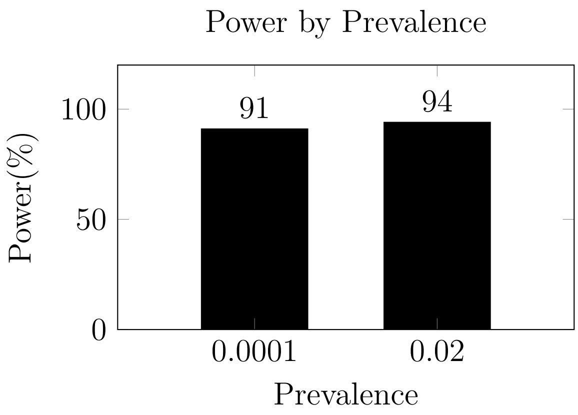


(b) Main Effect

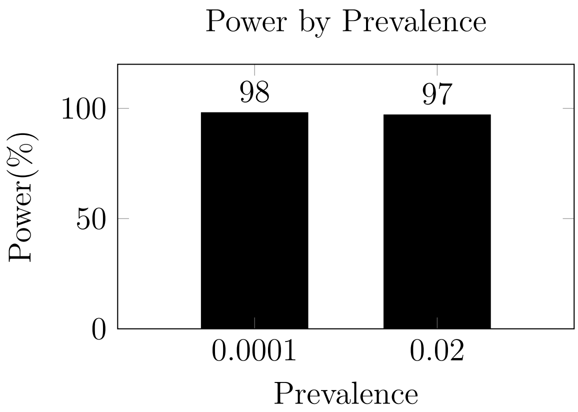


(c) Full Effect

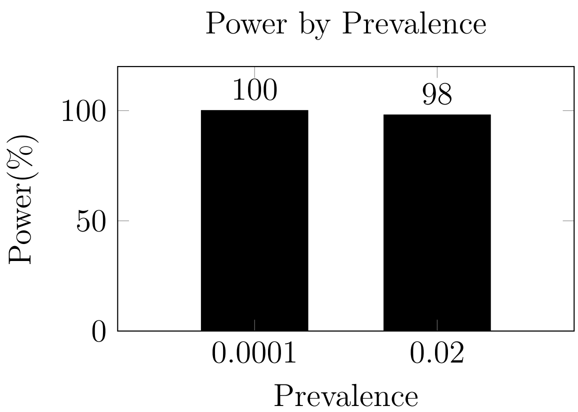
Figure 5: Distribution of the Power by odds ratios for all disease models. The allele frequency is 0.1, the population size is 2000 individuals, and the prevalence is 0.02.



(a) Epistasis

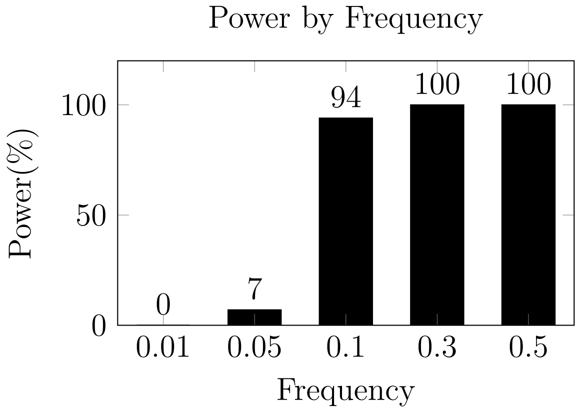


(b) Main Effect

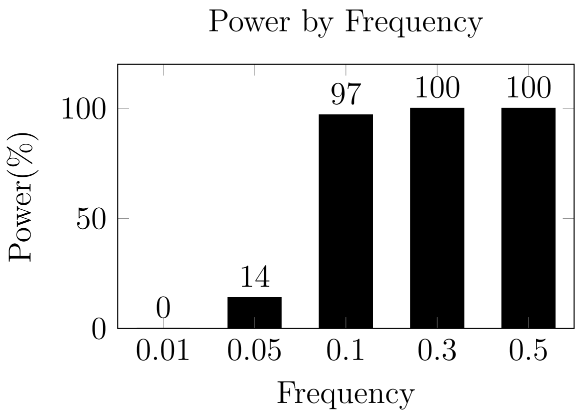


(c) Full Effect

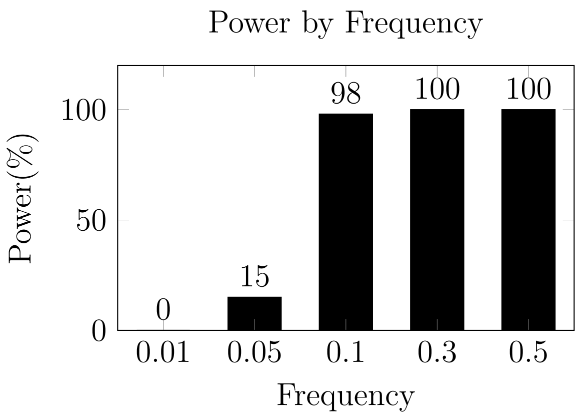
Figure 6: Distribution of the Power by prevalence for all disease models. The allele frequency is 0.1, the odds ratio is 2.0, and the population size is 2000 individuals.



(a) Epistasis



(b) Main Effect



(c) Full Effect

Figure 7: Distribution of the Power by allele frequency for all disease models. The population size is 2000 individuals, the odds ratio is 2.0, and the prevalence is 0.02.

B Table of Results

Table 1: A table containing the percentage of true positives and false positives in each configuration. The first column contains the description of the configuration. The second and third columns contain the number of datasets with true positives and false positives respectively, out of all 100 data sets per configuration.

Configuration*	TP (%)	FP (%)
0.5,500,I,2.0,0.02	26	4
0.5,500,I,2.0,0.0001	20	3
0.5,500,I,1.5,0.02	19	2
0.5,500,I,1.5,0.0001	1	4
0.5,500,I,1.1,0.02	0	1
0.5,500,I,1.1,0.0001	0	3
0.5,2000,I,2.0,0.02	100	8
0.5,2000,I,2.0,0.0001	100	17
0.5,2000,I,1.5,0.02	100	11
0.5,2000,I,1.5,0.0001	67	2
0.5,2000,I,1.1,0.02	15	6
0.5,2000,I,1.1,0.0001	7	7
0.5,1000,I,2.0,0.02	91	8
0.5,1000,I,2.0,0.0001	90	7
0.5,1000,I,1.5,0.02	79	8
0.5,1000,I,1.5,0.0001	13	4
0.5,1000,I,1.1,0.02	1	5
0.5,1000,I,1.1,0.0001	0	6
0.3,500,I,2.0,0.02	14	6
0.3,500,I,2.0,0.0001	46	6
0.3,500,I,1.5,0.02	15	3
0.3,500,I,1.5,0.0001	12	2
0.3,500,I,1.1,0.02	0	4
0.3,500,I,1.1,0.0001	0	1
0.3,2000,I,2.0,0.02	100	6
0.3,2000,I,2.0,0.0001	100	10
0.3,2000,I,1.5,0.02	100	30
0.3,2000,I,1.5,0.0001	100	10
0.3,2000,I,1.1,0.02	7	4
0.3,2000,I,1.1,0.0001	8	6
0.3,1000,I,2.0,0.02	66	2

0.3,1000,I,2.0,0.0001	100	8
0.3,1000,I,1.5,0.02	81	10
0.3,1000,I,1.5,0.0001	71	6
0.3,1000,I,1.1,0.02	0	2
0.3,1000,I,1.1,0.0001	0	3
0.1,500,I,2.0,0.02	1	7
0.1,500,I,2.0,0.0001	0	1
0.1,500,I,1.5,0.02	1	3
0.1,500,I,1.5,0.0001	1	5
0.1,500,I,1.1,0.02	0	7
0.1,500,I,1.1,0.0001	0	4
0.1,2000,I,2.0,0.02	94	21
0.1,2000,I,2.0,0.0001	91	7
0.1,2000,I,1.5,0.02	95	9
0.1,2000,I,1.5,0.0001	77	6
0.1,2000,I,1.1,0.02	27	5
0.1,2000,I,1.1,0.0001	24	2
0.1,1000,I,2.0,0.02	41	5
0.1,1000,I,2.0,0.0001	13	7
0.1,1000,I,1.5,0.02	36	4
0.1,1000,I,1.5,0.0001	10	3
0.1,1000,I,1.1,0.02	0	6
0.1,1000,I,1.1,0.0001	0	5
0.05,500,I,2.0,0.02	0	7
0.05,500,I,2.0,0.0001	1	2
0.05,500,I,1.5,0.02	0	8
0.05,500,I,1.5,0.0001	0	6
0.05,500,I,1.1,0.02	0	11
0.05,500,I,1.1,0.0001	0	3
0.05,2000,I,2.0,0.02	7	2
0.05,2000,I,2.0,0.0001	70	35
0.05,2000,I,1.5,0.02	65	49
0.05,2000,I,1.5,0.0001	47	28
0.05,2000,I,1.1,0.02	0	7
0.05,2000,I,1.1,0.0001	0	0
0.05,1000,I,2.0,0.02	0	4
0.05,1000,I,2.0,0.0001	8	8
0.05,1000,I,1.5,0.02	11	7

0.05,1000,I,1.5,0.0001	1	5
0.05,1000,I,1.1,0.02	0	4
0.05,1000,I,1.1,0.0001	0	6
0.01,500,I,2.0,0.02	0	4
0.01,500,I,2.0,0.0001	0	2
0.01,500,I,1.5,0.02	0	5
0.01,500,I,1.5,0.0001	0	4
0.01,500,I,1.1,0.02	0	5
0.01,500,I,1.1,0.0001	0	7
0.01,2000,I,2.0,0.02	0	2
0.01,2000,I,2.0,0.0001	1	6
0.01,2000,I,1.5,0.02	0	4
0.01,2000,I,1.5,0.0001	1	1
0.01,2000,I,1.1,0.02	0	2
0.01,2000,I,1.1,0.0001	0	6
0.01,1000,I,2.0,0.02	0	7
0.01,1000,I,2.0,0.0001	0	4
0.01,1000,I,1.5,0.02	0	2
0.01,1000,I,1.5,0.0001	0	4
0.01,1000,I,1.1,0.02	0	5
0.01,1000,I,1.1,0.0001	0	8
0.5,500,ME,2.0,0.02	100	97
0.5,500,ME,2.0,0.0001	100	95
0.5,500,ME,1.5,0.02	100	63
0.5,500,ME,1.5,0.0001	100	61
0.5,500,ME,1.1,0.02	81	30
0.5,500,ME,1.1,0.0001	78	22
0.5,2000,ME,2.0,0.02	100	100
0.5,2000,ME,2.0,0.0001	100	100
0.5,2000,ME,1.5,0.02	100	100
0.5,2000,ME,1.5,0.0001	100	100
0.5,2000,ME,1.1,0.02	100	100
0.5,2000,ME,1.1,0.0001	100	97
0.5,1000,ME,2.0,0.02	100	100
0.5,1000,ME,2.0,0.0001	100	100
0.5,1000,ME,1.5,0.02	100	100
0.5,1000,ME,1.5,0.0001	100	97
0.5,1000,ME,1.1,0.02	100	61

0.5,1000,ME,1.1,0.0001	100	59
0.3,500,ME,2.0,0.02	100	78
0.3,500,ME,2.0,0.0001	100	82
0.3,500,ME,1.5,0.02	90	29
0.3,500,ME,1.5,0.0001	86	33
0.3,500,ME,1.1,0.02	25	17
0.3,500,ME,1.1,0.0001	18	10
0.3,2000,ME,2.0,0.02	100	100
0.3,2000,ME,2.0,0.0001	100	100
0.3,2000,ME,1.5,0.02	100	99
0.3,2000,ME,1.5,0.0001	100	100
0.3,2000,ME,1.1,0.02	100	57
0.3,2000,ME,1.1,0.0001	100	51
0.3,1000,ME,2.0,0.02	100	99
0.3,1000,ME,2.0,0.0001	100	100
0.3,1000,ME,1.5,0.02	100	69
0.3,1000,ME,1.5,0.0001	100	66
0.3,1000,ME,1.1,0.02	92	28
0.3,1000,ME,1.1,0.0001	77	27
0.1,500,ME,2.0,0.02	2	12
0.1,500,ME,2.0,0.0001	8	14
0.1,500,ME,1.5,0.02	0	7
0.1,500,ME,1.5,0.0001	0	8
0.1,500,ME,1.1,0.02	0	7
0.1,500,ME,1.1,0.0001	0	4
0.1,2000,ME,2.0,0.02	97	74
0.1,2000,ME,2.0,0.0001	98	71
0.1,2000,ME,1.5,0.02	33	22
0.1,2000,ME,1.5,0.0001	34	23
0.1,2000,ME,1.1,0.02	2	11
0.1,2000,ME,1.1,0.0001	1	5
0.1,1000,ME,2.0,0.02	43	23
0.1,1000,ME,2.0,0.0001	50	32
0.1,1000,ME,1.5,0.02	5	9
0.1,1000,ME,1.5,0.0001	1	9
0.1,1000,ME,1.1,0.02	0	10
0.1,1000,ME,1.1,0.0001	0	5
0.05,500,ME,2.0,0.02	0	1

0.05,500,ME,2.0,0.0001	0	4
0.05,500,ME,1.5,0.02	0	1
0.05,500,ME,1.5,0.0001	0	2
0.05,500,ME,1.1,0.02	0	3
0.05,500,ME,1.1,0.0001	0	2
0.05,2000,ME,2.0,0.02	14	11
0.05,2000,ME,2.0,0.0001	13	10
0.05,2000,ME,1.5,0.02	2	2
0.05,2000,ME,1.5,0.0001	1	6
0.05,2000,ME,1.1,0.02	0	3
0.05,2000,ME,1.1,0.0001	2	3
0.05,1000,ME,2.0,0.02	1	3
0.05,1000,ME,2.0,0.0001	4	6
0.05,1000,ME,1.5,0.02	0	0
0.05,1000,ME,1.5,0.0001	1	3
0.05,1000,ME,1.1,0.02	0	3
0.05,1000,ME,1.1,0.0001	0	2
0.01,500,ME,2.0,0.02	0	1
0.01,500,ME,2.0,0.0001	0	7
0.01,500,ME,1.5,0.02	0	1
0.01,500,ME,1.5,0.0001	0	7
0.01,500,ME,1.1,0.02	0	1
0.01,500,ME,1.1,0.0001	0	7
0.01,2000,ME,2.0,0.02	0	1
0.01,2000,ME,2.0,0.0001	0	4
0.01,2000,ME,1.5,0.02	0	5
0.01,2000,ME,1.5,0.0001	0	5
0.01,2000,ME,1.1,0.02	0	5
0.01,2000,ME,1.1,0.0001	0	5
0.01,1000,ME,2.0,0.02	0	7
0.01,1000,ME,2.0,0.0001	0	3
0.01,1000,ME,1.5,0.02	0	8
0.01,1000,ME,1.5,0.0001	0	3
0.01,1000,ME,1.1,0.02	0	4
0.01,1000,ME,1.1,0.0001	0	2
0.5,500,ME+I,2.0,0.02	100	100
0.5,500,ME+I,2.0,0.0001	100	100
0.5,500,ME+I,1.5,0.02	100	100

0.5,500,ME+I,1.5,0.0001	100	100
0.5,500,ME+I,1.1,0.02	100	89
0.5,500,ME+I,1.1,0.0001	100	86
0.5,2000,ME+I,2.0,0.02	100	100
0.5,2000,ME+I,2.0,0.0001	100	100
0.5,2000,ME+I,1.5,0.02	100	100
0.5,2000,ME+I,1.5,0.0001	100	100
0.5,2000,ME+I,1.1,0.02	100	100
0.5,2000,ME+I,1.1,0.0001	100	100
0.5,1000,ME+I,2.0,0.02	100	100
0.5,1000,ME+I,2.0,0.0001	100	100
0.5,1000,ME+I,1.5,0.02	100	100
0.5,1000,ME+I,1.5,0.0001	100	100
0.5,1000,ME+I,1.1,0.02	100	100
0.5,1000,ME+I,1.1,0.0001	100	100
0.3,500,ME+I,2.0,0.02	100	100
0.3,500,ME+I,2.0,0.0001	100	100
0.3,500,ME+I,1.5,0.02	100	79
0.3,500,ME+I,1.5,0.0001	100	93
0.3,500,ME+I,1.1,0.02	79	28
0.3,500,ME+I,1.1,0.0001	89	25
0.3,2000,ME+I,2.0,0.02	100	100
0.3,2000,ME+I,2.0,0.0001	100	100
0.3,2000,ME+I,1.5,0.02	100	100
0.3,2000,ME+I,1.5,0.0001	100	100
0.3,2000,ME+I,1.1,0.02	100	97
0.3,2000,ME+I,1.1,0.0001	100	99
0.3,1000,ME+I,2.0,0.02	100	100
0.3,1000,ME+I,2.0,0.0001	100	100
0.3,1000,ME+I,1.5,0.02	100	99
0.3,1000,ME+I,1.5,0.0001	100	100
0.3,1000,ME+I,1.1,0.02	100	63
0.3,1000,ME+I,1.1,0.0001	100	66
0.1,500,ME+I,2.0,0.02	1	15
0.1,500,ME+I,2.0,0.0001	30	34
0.1,500,ME+I,1.5,0.02	0	10
0.1,500,ME+I,1.5,0.0001	1	10
0.1,500,ME+I,1.1,0.02	0	5

0.1,500,ME+I,1.1,0.0001	1	9
0.1,2000,ME+I,2.0,0.02	98	81
0.1,2000,ME+I,2.0,0.0001	100	100
0.1,2000,ME+I,1.5,0.02	72	51
0.1,2000,ME+I,1.5,0.0001	46	38
0.1,2000,ME+I,1.1,0.02	4	14
0.1,2000,ME+I,1.1,0.0001	2	16
0.1,1000,ME+I,2.0,0.02	42	38
0.1,1000,ME+I,2.0,0.0001	91	70
0.1,1000,ME+I,1.5,0.02	2	18
0.1,1000,ME+I,1.5,0.0001	8	18
0.1,1000,ME+I,1.1,0.02	0	13
0.1,1000,ME+I,1.1,0.0001	0	14
0.05,500,ME+I,2.0,0.02	0	4
0.05,500,ME+I,2.0,0.0001	0	11
0.05,500,ME+I,1.5,0.02	0	3
0.05,500,ME+I,1.5,0.0001	1	11
0.05,500,ME+I,1.1,0.02	0	8
0.05,500,ME+I,1.1,0.0001	0	7
0.05,2000,ME+I,2.0,0.02	15	17
0.05,2000,ME+I,2.0,0.0001	27	30
0.05,2000,ME+I,1.5,0.02	1	13
0.05,2000,ME+I,1.5,0.0001	4	8
0.05,2000,ME+I,1.1,0.02	0	7
0.05,2000,ME+I,1.1,0.0001	0	7
0.05,1000,ME+I,2.0,0.02	2	16
0.05,1000,ME+I,2.0,0.0001	8	11
0.05,1000,ME+I,1.5,0.02	1	6
0.05,1000,ME+I,1.5,0.0001	1	5
0.05,1000,ME+I,1.1,0.02	0	5
0.05,1000,ME+I,1.1,0.0001	0	6
0.01,500,ME+I,2.0,0.02	0	10
0.01,500,ME+I,2.0,0.0001	0	13
0.01,500,ME+I,1.5,0.02	0	13
0.01,500,ME+I,1.5,0.0001	0	12
0.01,500,ME+I,1.1,0.02	0	7
0.01,500,ME+I,1.1,0.0001	0	11
0.01,2000,ME+I,2.0,0.02	0	7

0.01,2000,ME+I,2.0,0.0001	0	12
0.01,2000,ME+I,1.5,0.02	0	13
0.01,2000,ME+I,1.5,0.0001	0	8
0.01,2000,ME+I,1.1,0.02	0	16
0.01,2000,ME+I,1.1,0.0001	0	8
0.01,1000,ME+I,2.0,0.02	0	11
0.01,1000,ME+I,2.0,0.0001	0	8
0.01,1000,ME+I,1.5,0.02	0	13
0.01,1000,ME+I,1.5,0.0001	0	7
0.01,1000,ME+I,1.1,0.02	0	10
0.01,1000,ME+I,1.1,0.0001	0	3

*MAF,POP,MOD,OR,PREV where MAF represents the minor allele frequency, POP is the number of individuals, MOD is the used model (with or without main effect and with or without epistasis effect), OR is the odds ratio and PREV is the prevalence of the disease.

Table 2: A table containing the running time, cpu usage and memory usage in each configuration.

Configuration*	Running Time (s)	CPU Usage (%)	Memory Usage (KB)
0.5,500,ME+I,2.0,0.02	0.16	95.70	1003.04
0.5,500,ME+I,2.0,0.0001	0.16	96.05	1003.56
0.5,500,ME+I,1.5,0.02	0.16	96.07	1001.04
0.5,500,ME+I,1.5,0.0001	0.16	95.08	991.88
0.5,500,ME+I,1.1,0.02	0.16	96.93	995.92
0.5,500,ME+I,1.1,0.0001	0.16	95.35	973.64
0.5,500,ME,2.0,0.02	0.16	96.97	997.92
0.5,500,ME,2.0,0.0001	0.16	95.79	980.40
0.5,500,ME,1.5,0.02	0.16	97.07	996.76
0.5,500,ME,1.5,0.0001	0.16	98.08	972.08
0.5,500,ME,1.1,0.02	0.16	97.83	993.84
0.5,500,ME,1.1,0.0001	0.16	97.93	971.52
0.5,500,I,2.0,0.02	0.16	98.11	996.16
0.5,500,I,2.0,0.0001	0.16	98.02	973.60
0.5,500,I,1.5,0.02	0.16	97.67	998.08
0.5,500,I,1.5,0.0001	0.16	98.41	970.00
0.5,500,I,1.1,0.02	0.16	97.59	995.36
0.5,500,I,1.1,0.0001	0.16	97.38	967.72

0.5,2000,ME+I,2.0,0.02	0.34	97.87	1226.44
0.5,2000,ME+I,2.0,0.0001	0.34	97.56	1217.20
0.5,2000,ME+I,1.5,0.02	0.32	97.89	1190.48
0.5,2000,ME+I,1.5,0.0001	0.32	97.26	1188.16
0.5,2000,ME+I,1.1,0.02	0.31	97.13	1171.92
0.5,2000,ME+I,1.1,0.0001	0.31	97.29	1171.28
0.5,2000,ME,2.0,0.02	0.32	97.95	1175.04
0.5,2000,ME,2.0,0.0001	0.32	97.69	1174.32
0.5,2000,ME,1.5,0.02	0.31	97.78	1169.32
0.5,2000,ME,1.5,0.0001	0.31	98.06	1168.92
0.5,2000,ME,1.1,0.02	0.31	97.20	1155.96
0.5,2000,ME,1.1,0.0001	0.31	97.86	1142.44
0.5,2000,I,2.0,0.02	0.31	98.14	1146.04
0.5,2000,I,2.0,0.0001	0.31	97.71	1134.80
0.5,2000,I,1.5,0.02	0.31	97.82	1155.12
0.5,2000,I,1.5,0.0001	0.31	98.39	1132.64
0.5,2000,I,1.1,0.02	0.31	97.77	1149.60
0.5,2000,I,1.1,0.0001	0.31	98.57	1127.76
0.5,1000,ME+I,2.0,0.02	0.22	98.79	1071.92
0.5,1000,ME+I,2.0,0.0001	0.22	98.28	1053.88
0.5,1000,ME+I,1.5,0.02	0.22	95.92	1059.68
0.5,1000,ME+I,1.5,0.0001	0.22	96.97	1046.96
0.5,1000,ME+I,1.1,0.02	0.21	97.21	1053.52
0.5,1000,ME+I,1.1,0.0001	0.21	98.45	1028.16
0.5,1000,ME,2.0,0.02	0.22	98.66	1056.92
0.5,1000,ME,2.0,0.0001	0.21	98.77	1036.44
0.5,1000,ME,1.5,0.02	0.21	98.88	1049.04
0.5,1000,ME,1.5,0.0001	0.21	98.09	1016.32
0.5,1000,ME,1.1,0.02	0.21	98.19	1043.88
0.5,1000,ME,1.1,0.0001	0.21	98.18	1002.92
0.5,1000,I,2.0,0.02	0.21	97.86	1045.96
0.5,1000,I,2.0,0.0001	0.21	97.54	1003.00
0.5,1000,I,1.5,0.02	0.21	96.90	1048.20
0.5,1000,I,1.5,0.0001	0.21	97.46	1006.16
0.5,1000,I,1.1,0.02	0.21	96.44	1044.28
0.5,1000,I,1.1,0.0001	0.21	97.60	1000.88
0.3,500,ME+I,2.0,0.02	0.16	98.13	998.44
0.3,500,ME+I,2.0,0.0001	0.16	98.23	1003.00

0.3,500,ME+I,1.5,0.02	0.16	97.97	996.72
0.3,500,ME+I,1.5,0.0001	0.16	98.37	983.32
0.3,500,ME+I,1.1,0.02	0.16	98.12	997.60
0.3,500,ME+I,1.1,0.0001	0.16	97.90	966.76
0.3,500,ME,2.0,0.02	0.16	98.13	998.60
0.3,500,ME,2.0,0.0001	0.16	98.44	971.80
0.3,500,ME,1.5,0.02	0.16	98.78	997.36
0.3,500,ME,1.5,0.0001	0.16	98.05	969.24
0.3,500,ME,1.1,0.02	0.16	98.11	996.00
0.3,500,ME,1.1,0.0001	0.16	98.36	968.72
0.3,500,I,2.0,0.02	0.16	98.39	997.20
0.3,500,I,2.0,0.0001	0.16	98.55	978.32
0.3,500,I,1.5,0.02	0.16	98.36	995.88
0.3,500,I,1.5,0.0001	0.16	97.51	964.56
0.3,500,I,1.1,0.02	0.16	97.83	997.64
0.3,500,I,1.1,0.0001	0.16	97.29	968.68
0.3,2000,ME+I,2.0,0.02	0.32	97.82	1184.36
0.3,2000,ME+I,2.0,0.0001	0.34	96.01	1225.96
0.3,2000,ME+I,1.5,0.02	0.31	96.61	1171.32
0.3,2000,ME+I,1.5,0.0001	0.32	96.50	1175.60
0.3,2000,ME+I,1.1,0.02	0.31	96.16	1150.92
0.3,2000,ME+I,1.1,0.0001	0.31	97.24	1148.96
0.3,2000,ME,2.0,0.02	0.31	97.27	1170.44
0.3,2000,ME,2.0,0.0001	0.31	95.77	1171.48
0.3,2000,ME,1.5,0.02	0.31	96.48	1160.12
0.3,2000,ME,1.5,0.0001	0.31	97.31	1151.52
0.3,2000,ME,1.1,0.02	0.31	96.43	1150.12
0.3,2000,ME,1.1,0.0001	0.31	95.85	1129.60
0.3,2000,I,2.0,0.02	0.31	95.56	1153.76
0.3,2000,I,2.0,0.0001	0.31	95.81	1131.24
0.3,2000,I,1.5,0.02	0.31	97.12	1154.00
0.3,2000,I,1.5,0.0001	0.31	98.11	1134.88
0.3,2000,I,1.1,0.02	0.31	97.10	1147.48
0.3,2000,I,1.1,0.0001	0.31	95.79	1128.28
0.3,1000,ME+I,2.0,0.02	0.21	94.97	1058.36
0.3,1000,ME+I,2.0,0.0001	0.22	96.59	1059.72
0.3,1000,ME+I,1.5,0.02	0.21	96.59	1053.20
0.3,1000,ME+I,1.5,0.0001	0.21	96.29	1043.68

0.3,1000,ME+I,1.1,0.02	0.21	98.29	1047.48
0.3,1000,ME+I,1.1,0.0001	0.21	97.93	1006.04
0.3,1000,ME,2.0,0.02	0.21	97.33	1047.56
0.3,1000,ME,2.0,0.0001	0.21	98.02	1025.24
0.3,1000,ME,1.5,0.02	0.21	95.34	1048.40
0.3,1000,ME,1.5,0.0001	0.21	95.54	1006.60
0.3,1000,ME,1.1,0.02	0.21	96.92	1040.96
0.3,1000,ME,1.1,0.0001	0.21	97.23	1001.80
0.3,1000,I,2.0,0.02	0.21	97.65	1046.96
0.3,1000,I,2.0,0.0001	0.21	96.54	1010.36
0.3,1000,I,1.5,0.02	0.21	95.78	1051.16
0.3,1000,I,1.5,0.0001	0.21	96.49	1006.16
0.3,1000,I,1.1,0.02	0.21	96.77	1045.64
0.3,1000,I,1.1,0.0001	0.21	96.72	999.52
0.1,500,ME+I,2.0,0.02	0.16	96.61	995.84
0.1,500,ME+I,2.0,0.0001	0.16	95.81	971.08
0.1,500,ME+I,1.5,0.02	0.16	95.41	995.32
0.1,500,ME+I,1.5,0.0001	0.16	97.03	966.40
0.1,500,ME+I,1.1,0.02	0.16	96.58	995.56
0.1,500,ME+I,1.1,0.0001	0.16	97.02	973.00
0.1,500,ME,2.0,0.02	0.16	96.29	995.56
0.1,500,ME,2.0,0.0001	0.16	96.80	968.88
0.1,500,ME,1.5,0.02	0.16	95.68	999.52
0.1,500,ME,1.5,0.0001	0.16	96.15	968.08
0.1,500,ME,1.1,0.02	0.16	95.78	996.88
0.1,500,ME,1.1,0.0001	0.16	96.61	968.36
0.1,500,I,2.0,0.02	0.16	96.69	996.84
0.1,500,I,2.0,0.0001	0.16	96.31	970.08
0.1,500,I,1.5,0.02	0.16	96.01	996.00
0.1,500,I,1.5,0.0001	0.16	95.68	970.40
0.1,500,I,1.1,0.02	0.16	95.82	996.20
0.1,500,I,1.1,0.0001	0.16	96.19	969.84
0.1,2000,ME+I,2.0,0.02	0.31	96.47	1154.56
0.1,2000,ME+I,2.0,0.0001	0.31	97.14	1157.40
0.1,2000,ME+I,1.5,0.02	0.31	97.21	1151.28
0.1,2000,ME+I,1.5,0.0001	0.31	98.25	1131.32
0.1,2000,ME+I,1.1,0.02	0.31	98.12	1148.64
0.1,2000,ME+I,1.1,0.0001	0.31	96.25	1125.76

0.1,2000,ME,2.0,0.02	0.31	97.41	1153.04
0.1,2000,ME,2.0,0.0001	0.31	97.62	1139.76
0.1,2000,ME,1.5,0.02	0.31	97.73	1149.56
0.1,2000,ME,1.5,0.0001	0.31	97.73	1131.12
0.1,2000,ME,1.1,0.02	0.31	97.87	1148.72
0.1,2000,ME,1.1,0.0001	0.31	97.22	1129.48
0.1,2000,I,2.0,0.02	0.31	97.24	1150.88
0.1,2000,I,2.0,0.0001	0.31	95.68	1133.92
0.1,2000,I,1.5,0.02	0.31	94.91	1151.36
0.1,2000,I,1.5,0.0001	0.31	95.62	1135.04
0.1,2000,I,1.1,0.02	0.31	94.25	1148.12
0.1,2000,I,1.1,0.0001	0.31	96.06	1132.36
0.1,1000,ME+I,2.0,0.02	0.21	97.34	1043.80
0.1,1000,ME+I,2.0,0.0001	0.21	97.42	1012.40
0.1,1000,ME+I,1.5,0.02	0.21	97.26	1044.76
0.1,1000,ME+I,1.5,0.0001	0.21	97.05	1000.32
0.1,1000,ME+I,1.1,0.02	0.21	96.66	1042.76
0.1,1000,ME+I,1.1,0.0001	0.21	98.06	1000.16
0.1,1000,ME,2.0,0.02	0.21	97.68	1043.00
0.1,1000,ME,2.0,0.0001	0.21	97.66	1003.92
0.1,1000,ME,1.5,0.02	0.21	97.74	1043.64
0.1,1000,ME,1.5,0.0001	0.21	97.69	1001.60
0.1,1000,ME,1.1,0.02	0.21	97.95	1046.68
0.1,1000,ME,1.1,0.0001	0.21	97.83	1002.68
0.1,1000,I,2.0,0.02	0.21	96.10	1046.00
0.1,1000,I,2.0,0.0001	0.21	95.81	1003.88
0.1,1000,I,1.5,0.02	0.21	96.72	1041.84
0.1,1000,I,1.5,0.0001	0.21	96.96	1000.64
0.1,1000,I,1.1,0.02	0.21	96.48	1045.88
0.1,1000,I,1.1,0.0001	0.21	96.97	1003.84
0.05,500,ME+I,2.0,0.02	0.16	97.24	997.76
0.05,500,ME+I,2.0,0.0001	0.16	96.63	969.04
0.05,500,ME+I,1.5,0.02	0.16	97.31	995.32
0.05,500,ME+I,1.5,0.0001	0.16	97.56	966.84
0.05,500,ME+I,1.1,0.02	0.16	97.33	995.60
0.05,500,ME+I,1.1,0.0001	0.16	97.15	969.08
0.05,500,ME,2.0,0.02	0.16	96.23	997.08
0.05,500,ME,2.0,0.0001	0.16	97.46	971.00

0.05,500,ME,1.5,0.02	0.16	97.55	994.76
0.05,500,ME,1.5,0.0001	0.16	96.71	967.52
0.05,500,ME,1.1,0.02	0.16	95.80	995.36
0.05,500,ME,1.1,0.0001	0.16	96.52	969.68
0.05,500,I,2.0,0.02	0.16	98.23	995.56
0.05,500,I,2.0,0.0001	0.16	96.40	967.08
0.05,500,I,1.5,0.02	0.16	96.81	998.12
0.05,500,I,1.5,0.0001	0.16	96.51	971.36
0.05,500,I,1.1,0.02	0.16	96.55	996.88
0.05,500,I,1.1,0.0001	0.16	96.97	973.32
0.05,2000,ME+I,2.0,0.02	0.31	98.08	1149.36
0.05,2000,ME+I,2.0,0.0001	0.31	97.88	1131.84
0.05,2000,ME+I,1.5,0.02	0.31	97.97	1145.80
0.05,2000,ME+I,1.5,0.0001	0.31	97.98	1127.56
0.05,2000,ME+I,1.1,0.02	0.31	97.77	1145.32
0.05,2000,ME+I,1.1,0.0001	0.31	98.04	1127.08
0.05,2000,ME,2.0,0.02	0.31	98.05	1149.92
0.05,2000,ME,2.0,0.0001	0.31	98.14	1128.48
0.05,2000,ME,1.5,0.02	0.31	98.21	1146.80
0.05,2000,ME,1.5,0.0001	0.31	98.15	1128.40
0.05,2000,ME,1.1,0.02	0.31	98.11	1148.16
0.05,2000,ME,1.1,0.0001	0.31	97.26	1124.52
0.05,2000,I,2.0,0.02	0.31	97.86	1126.84
0.05,2000,I,2.0,0.0001	0.31	97.84	1135.60
0.05,2000,I,1.5,0.02	0.31	98.56	1155.56
0.05,2000,I,1.5,0.0001	0.31	98.07	1134.72
0.05,2000,I,1.1,0.02	0.31	97.36	1145.32
0.05,2000,I,1.1,0.0001	0.31	98.04	1127.44
0.05,1000,ME+I,2.0,0.02	0.21	96.67	1042.08
0.05,1000,ME+I,2.0,0.0001	0.21	96.80	999.68
0.05,1000,ME+I,1.5,0.02	0.21	95.98	1043.12
0.05,1000,ME+I,1.5,0.0001	0.21	97.60	1000.24
0.05,1000,ME+I,1.1,0.02	0.21	97.59	1044.92
0.05,1000,ME+I,1.1,0.0001	0.21	97.92	998.92
0.05,1000,ME,2.0,0.02	0.21	95.85	1044.24
0.05,1000,ME,2.0,0.0001	0.21	96.70	1001.08
0.05,1000,ME,1.5,0.02	0.21	97.88	1041.64
0.05,1000,ME,1.5,0.0001	0.21	97.31	998.80

0.05,1000,ME,1.1,0.02	0.21	97.01	1043.12
0.05,1000,ME,1.1,0.0001	0.21	98.04	1000.96
0.05,1000,I,2.0,0.02	0.21	97.76	1039.76
0.05,1000,I,2.0,0.0001	0.21	97.61	1006.80
0.05,1000,I,1.5,0.02	0.22	97.33	1045.32
0.05,1000,I,1.5,0.0001	0.21	97.58	1000.04
0.05,1000,I,1.1,0.02	0.21	97.67	1043.52
0.05,1000,I,1.1,0.0001	0.21	97.16	1000.44
0.01,500,ME+I,2.0,0.02	0.16	95.84	995.28
0.01,500,ME+I,2.0,0.0001	0.16	96.53	967.96
0.01,500,ME+I,1.5,0.02	0.16	97.68	995.84
0.01,500,ME+I,1.5,0.0001	0.16	97.60	971.52
0.01,500,ME+I,1.1,0.02	0.16	96.47	995.80
0.01,500,ME+I,1.1,0.0001	0.16	97.49	965.56
0.01,500,ME,2.0,0.02	0.16	96.47	995.40
0.01,500,ME,2.0,0.0001	0.16	97.93	965.68
0.01,500,ME,1.5,0.02	0.16	97.54	995.92
0.01,500,ME,1.5,0.0001	0.16	96.80	965.56
0.01,500,ME,1.1,0.02	0.16	98.11	995.92
0.01,500,ME,1.1,0.0001	0.16	97.90	965.64
0.01,500,I,2.0,0.02	0.16	96.09	997.20
0.01,500,I,2.0,0.0001	0.16	96.16	968.28
0.01,500,I,1.5,0.02	0.16	95.26	997.04
0.01,500,I,1.5,0.0001	0.16	97.09	968.28
0.01,500,I,1.1,0.02	0.16	97.41	994.24
0.01,500,I,1.1,0.0001	0.16	97.18	966.48
0.01,2000,ME+I,2.0,0.02	0.31	97.00	1146.36
0.01,2000,ME+I,2.0,0.0001	0.31	96.89	1128.12
0.01,2000,ME+I,1.5,0.02	0.31	96.86	1140.88
0.01,2000,ME+I,1.5,0.0001	0.31	97.57	1125.52
0.01,2000,ME+I,1.1,0.02	0.31	97.07	1148.24
0.01,2000,ME+I,1.1,0.0001	0.31	98.56	1125.16
0.01,2000,ME,2.0,0.02	0.31	98.16	1145.76
0.01,2000,ME,2.0,0.0001	0.31	97.32	1128.20
0.01,2000,ME,1.5,0.02	0.31	97.36	1140.92
0.01,2000,ME,1.5,0.0001	0.31	97.76	1125.64
0.01,2000,ME,1.1,0.02	0.31	98.06	1140.92
0.01,2000,ME,1.1,0.0001	0.31	97.91	1125.76

0.01,2000,I,2.0,0.02	0.31	98.10	1144.24
0.01,2000,I,2.0,0.0001	0.31	98.33	1128.08
0.01,2000,I,1.5,0.02	0.31	97.82	1148.32
0.01,2000,I,1.5,0.0001	0.31	97.97	1128.08
0.01,2000,I,1.1,0.02	0.31	97.91	1144.64
0.01,2000,I,1.1,0.0001	0.31	98.36	1125.80
0.01,1000,ME+I,2.0,0.02	0.21	97.16	1046.00
0.01,1000,ME+I,2.0,0.0001	0.21	97.67	1001.36
0.01,1000,ME+I,1.5,0.02	0.21	97.29	1043.36
0.01,1000,ME+I,1.5,0.0001	0.21	97.29	998.12
0.01,1000,ME+I,1.1,0.02	0.21	97.45	1046.16
0.01,1000,ME+I,1.1,0.0001	0.21	97.45	1000.64
0.01,1000,ME,2.0,0.02	0.21	97.59	1043.72
0.01,1000,ME,2.0,0.0001	0.21	97.19	998.16
0.01,1000,ME,1.5,0.02	0.21	96.83	1042.20
0.01,1000,ME,1.5,0.0001	0.21	97.27	998.08
0.01,1000,ME,1.1,0.02	0.21	97.37	1046.36
0.01,1000,ME,1.1,0.0001	0.21	97.50	1000.84
0.01,1000,I,2.0,0.02	0.21	97.94	1044.48
0.01,1000,I,2.0,0.0001	0.21	96.81	1001.80
0.01,1000,I,1.5,0.02	0.21	97.98	1043.52
0.01,1000,I,1.5,0.0001	0.21	98.02	1000.44
0.01,1000,I,1.1,0.02	0.21	97.05	1042.88
0.01,1000,I,1.1,0.0001	0.21	97.81	1002.12

*MAF,POP,MOD,OR,PREV where MAF represents the minor allele frequency, POP is the number of individuals, MOD is the used model (with or without main effect and with or without epistasis effect), OR is the odds ratio and PREV is the prevalence of the disease.