

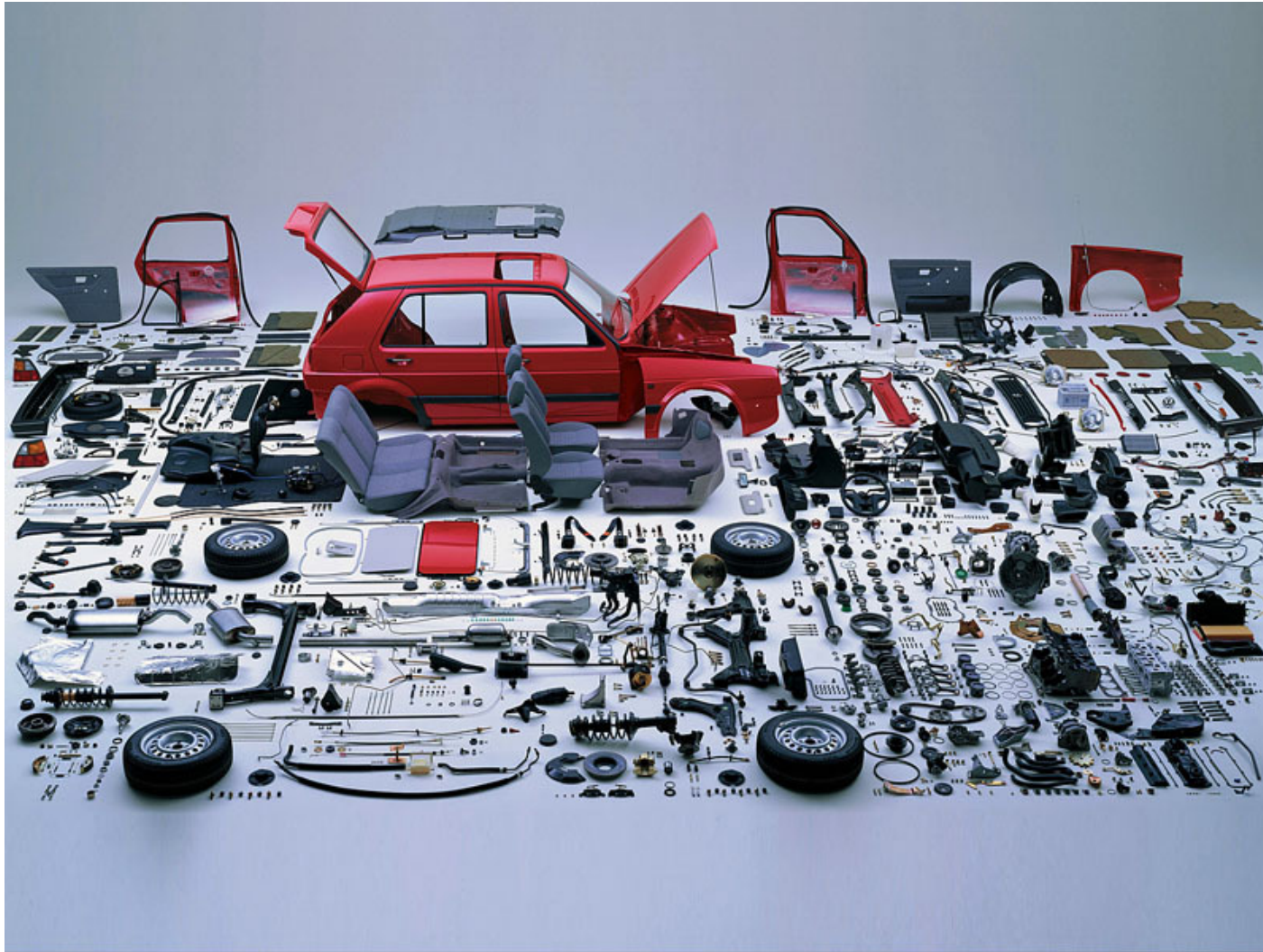
Efficiently improving a Black Box model characterized by a million parameters

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Volvo Technology

Chalmers

The problem



Parameters characterizing a washer

ÄNDRINGENFÖRÄNDRINGEN CHANGE INFORMATION	NUMMERNUMBER	IS-LÄS-LÄS CLASS	GRUPPGRUPP CLASSIFICATION	STANDARD
R187	2001-02-18		Se AI / See CI	

RUNDBRICKOR PLAIN WASHERS	PLAIN WASHERS
Stål Höfö-zinkade zink-järn, svankromaterade	Steel Electro-zincplated, black chromated

KRAV

Material

Stål med hårdhet enligt tabell.

Ytbehandling

Elektrozinkade Fe/Zn-le 8 C₄ STD 5732,104.

Övriga krav

Tillverkningsöversnittet 81 D 7151,57

Fria från groser, skarpa kanter och andra defekter som minskar användbarheten.

Konsekvensklass [4] gäller för ej markerade egenskaper.

Symboler, beteckningar och allmänt ritstätt
STD 5023,501

REQUIREMENTS

Material

Steel with hardness as per table.

Surface treatment

Electro-zincplated Fe/Zn-Fe 8 C₄ STD 5732,104.

Other requirements

Manufacturing specifications STD 7151.52

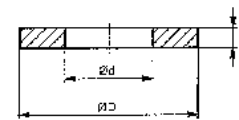
Free from burrs, sharp edges and other defects which may lessen the usability.

Consequence class [4] applies to properties not marked.

Symbols, designations and general drawing methods STD 5023,501.

Dimensioner

Dimensions



d	D	T	Hårdhet Hardness H _B	Avseende för diameter Intended for diameter M-gånga M-thread	Avseende för diameter Intended for diameter UN-gånga UN-thread	Art nr Part No.
3,2	6	0,5	min 90	3	nrNo. 5	855880
3,7	7	0,8	min 90	3,5	nrNo. 6	843120
4,3	8	0,8	min 90	4	nrNo. 8	855881
4,8	10	0,5	min 90	4,5	-	860186
5,3	10	1	min 90	5	nrNo. 10	840090
6,4	12	1,5	min 200	6	nrNo. 12	855882
6,7	14	1,5	min 200	-	1/4	855883
7,4	14	1,5	min 200	7	-	860147
8,4	18	1,5	min 200	8	5/16	855884
10	18	2	min 200	-	3/8	840097
10,5	22	2	min 200	10	-	860148
12	22	2	min 200	-	7/16	855886
13	24	2	min 200	12	-	855887
13,5	24	2	min 200	-	1/2	860098
15	26	2	min 200	14	5/16	855888
17	30	3	min 200	16	3/2	855900
18	34	3	min 200	18	-	855901
20	36	3	min 200	-	3/4	855902
21	36	3	min 200	20	-	855903
23	40	3	min 200	22	7/8	855904
25	45	4	min 200	24	-	855905
26	45	4	min 200	-	1	855906
28	50	4	min 200	27	-	850149
30	52	4	min 200	-	1 1/8	855907
31	58	4	min 200	30	-	860150
33	58	4	min 200	-	1 1/4	855908
34	62	4	min 200	33	-	860151

För samtliga anmärkningar gäller artikelteckning / artikelbeteckning P01

Part issue / Part version: P01 applies to all parts

(Uppgift om artikelteckning gäller för Volvo Personbilar)

Information on part issue does not apply to Volvo Car Corporation

95-10-12, S Larsson	1152	95-10-12, S Larsson	1152
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TABELLRITNING TABULAR DRAWING			
1052700	002	1 (3)	

VOLVO Volvo Corporate Standards			
BENÄMNING Name			
Washer d x D x T			
1052700	002	2 (3)	

The present solutions

Design of experiments factorial design

- Twice as many experiments as the number of variables

Efficient Black Box optimization

- More than twice the number of experiments than the number of variables

DoE Super saturated designs

- Half the number of experiments as the number of variables

Super saturated design

- $Ax=b$
- More columns than rows in A
- The columns are as little correlated as possible
- Variable selection is used which means that only the largest elements in x are calculated

New method: Lean optimization

- $Ax=b$
- The solving is by minimum norm, not variable selection
- The rows are independent, not the columns
- Rows of A are much less than columns

- The gain is square root of (rows*columns)

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$$Ax=b$$

Constant	size	capacity	speed	footprint
	persons	kg	km/h	gha
1	2	500	90	0.34
1	2	800	180	0.55
1	5	500	180	0.46
1	5	800	90	0.49
0.03	0.01	0.0004	0.001	

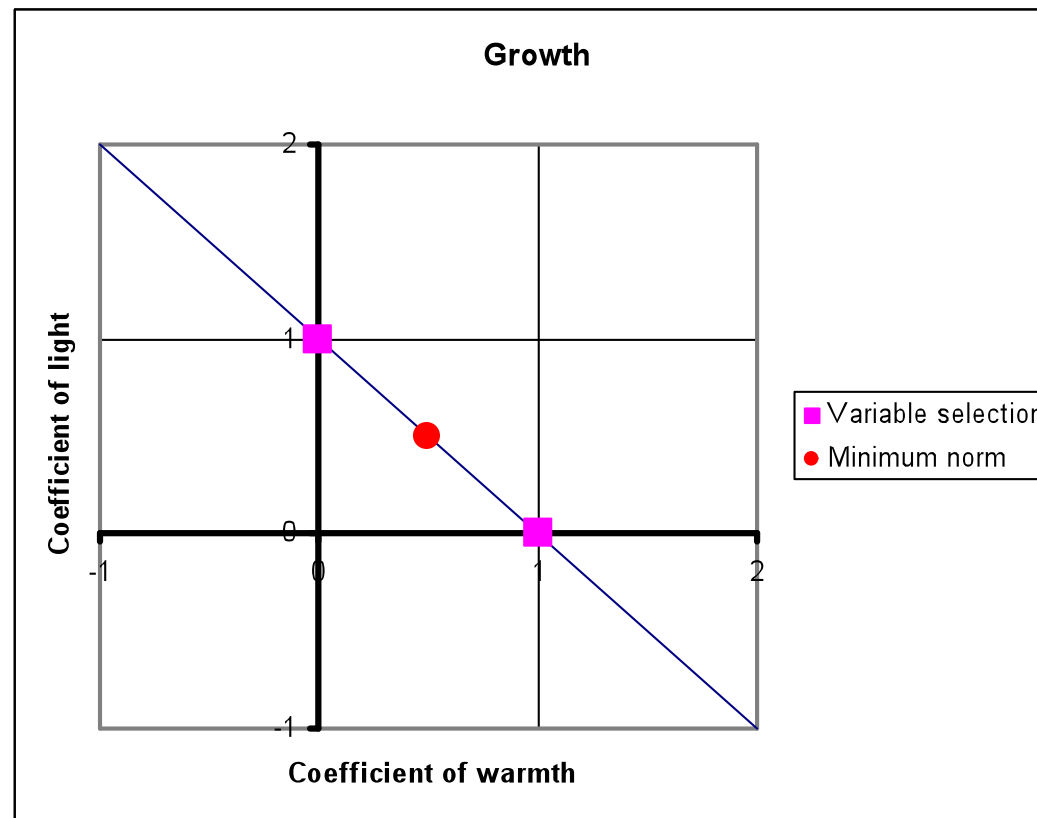
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Minimum norm solution

Warmth	Light	Growth
0	0	0
1	1	1



Calculating minimum norm solution

- $Ax=b$
- $Svd(A)=USV^T$
 - S is $\sqrt{eig(A^T A)}$, U and V are eigenvectors of $A^T A$ and AA^T respectively
- Minimum norm inverse $=A^+=VS^{-1}U^T$

Where S^{-1} is S^T with inverse of the nonzero diagonal elements
- In Matlab $A^+=pinv(A)$ (not $A\backslash$)

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Why independent columns for least square solution?

- $Ax=b$ $\hat{x}=A^+b$
- For least square solution
 - $\hat{b}=A^+A^+b$
 - If rows less than columns $A^+A^+=I$
 - If columns less than rows, columns should be orthogonal so \hat{b} correlates as good as possibly with b

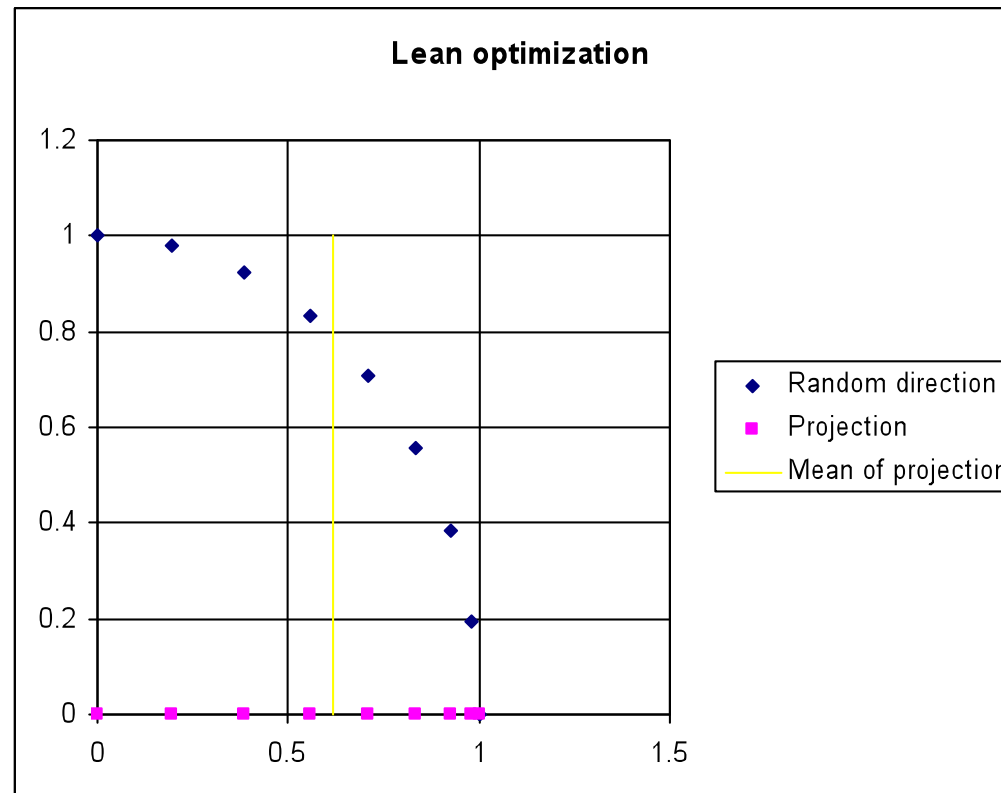
Why independent rows for minimum norm solution?

- $b=Ax$ $\hat{x}=A^{+*}b=A^{+*}A^*x$
- For minimum norm solution
 - $\hat{x}=A^{+*}A^*x$
 - If columns less than rows $A^{+*}A=I$
 - If rows less than columns, rows should be orthogonal so \hat{x} correlates as good as possibly with x

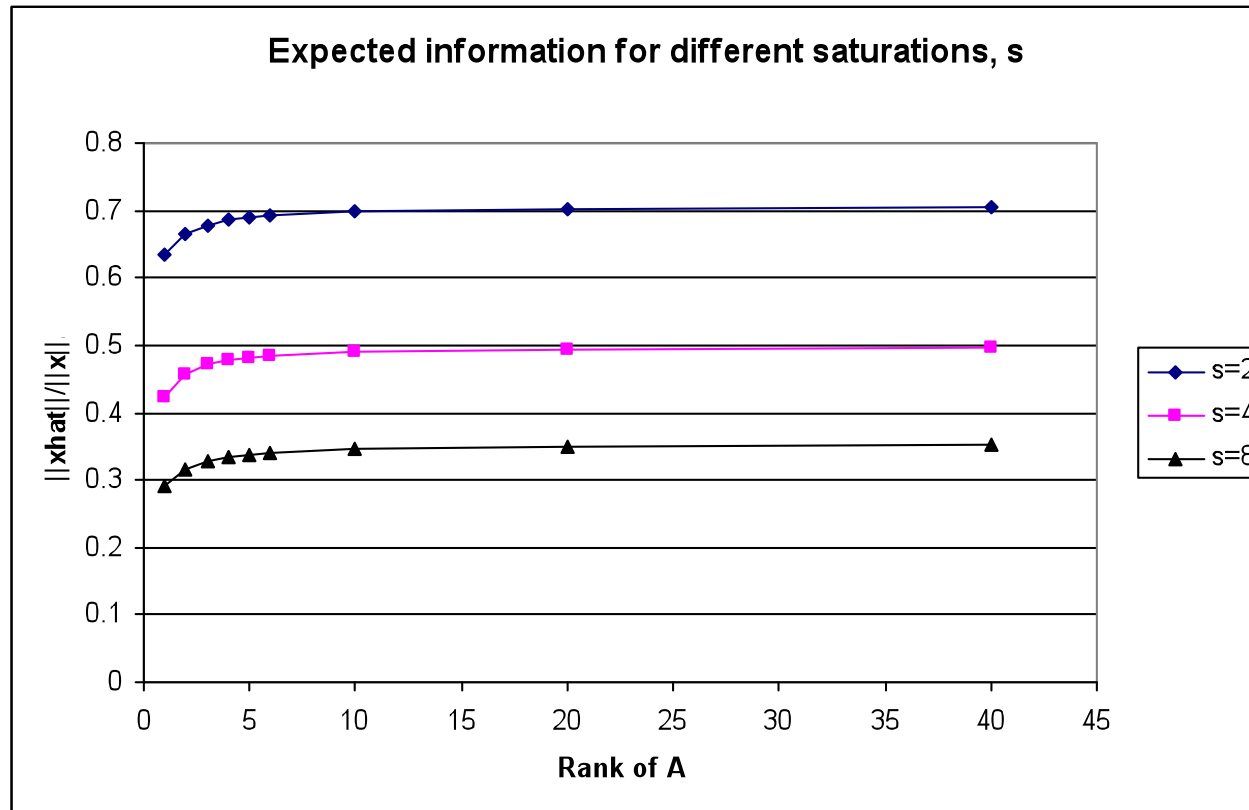
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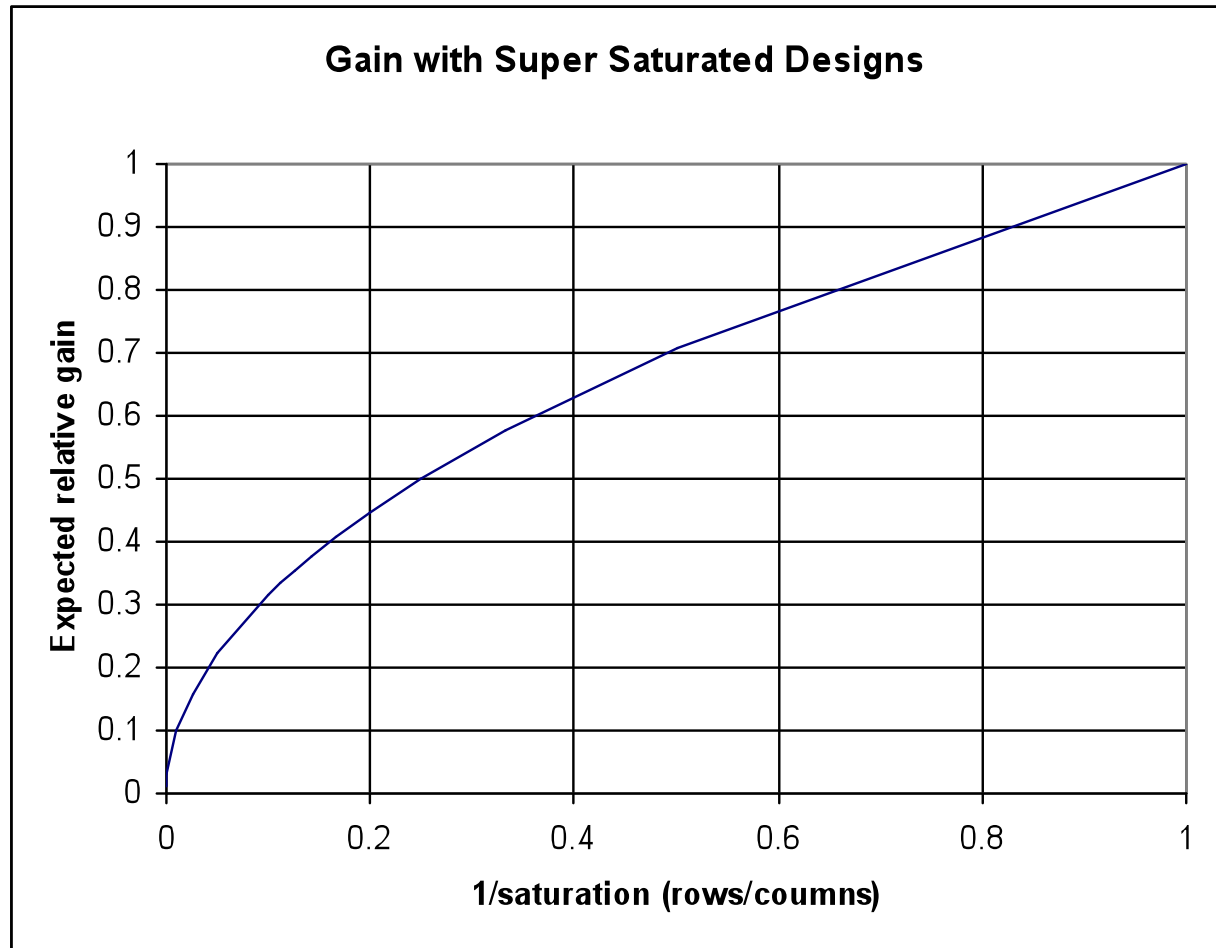
Gain of one dimension of two



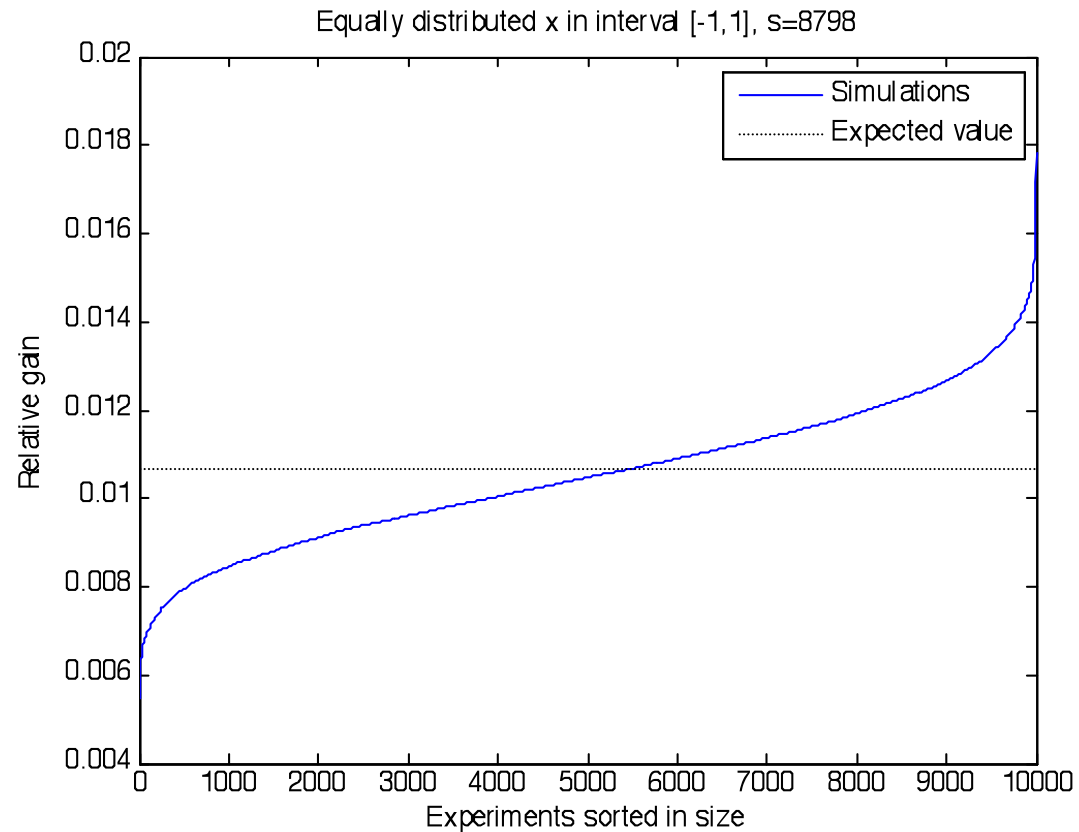
Gain if #columns=2,4,8#rows



Gain of arbitrary saturation



Simulation of equal distribution



Gain of Lean optimization

- For a lean optimization, the relative gain is square root of ($\#rows/\#columns$)
- The maximal gain is $\#columns$
- The gain of Lean optimization is
– square root of ($\#rows * \#columns$)

New method: Lean optimization

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Thank you for
your attention