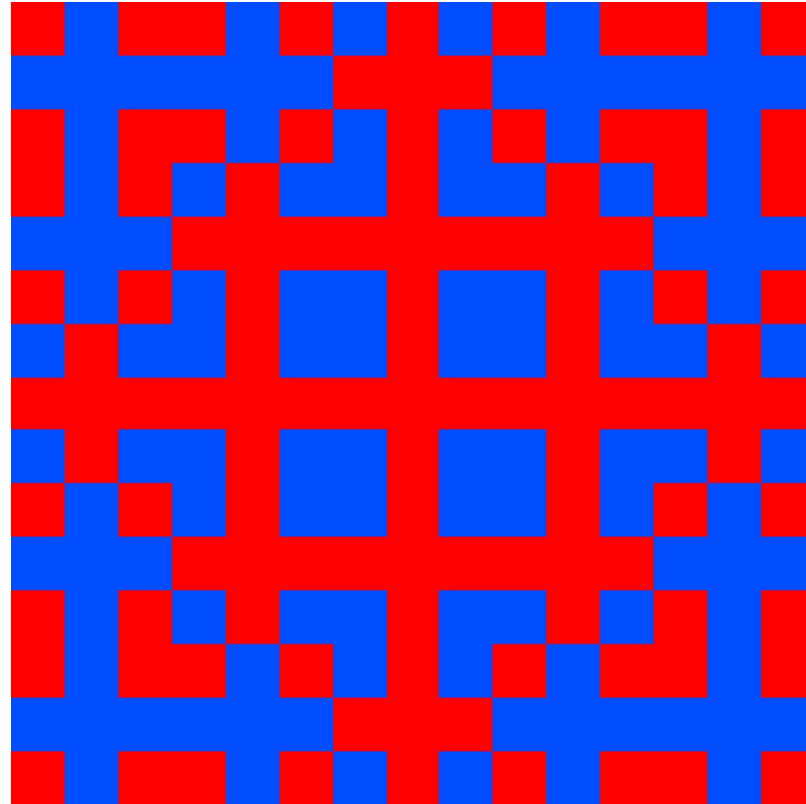


Hans Walser



Magische Quadrate

www.walser-h-m.ch/hans/Vortraege/20220407

6	7	2
1	5	9
8	3	4

Magisches Quadrat ungerader Seitenlänge

Handout

Mit den *ungeraden* Zahlen von 1 bis 25 zum magischen Quadrat ergänzen

14	20		2	8
10				4
22				16
18	24		6	12

Handout

Mit den *ungeraden* Zahlen von 1 bis 121 zum magischen Quadrat ergänzen

62	74	86	98	110		2	14	26	38	50
52	64	76	88				4	16	28	40
42	54	66						6	18	30
32	44								8	20
22										10
112										100
102	114								78	90
92	104	116						56	68	80
82	94	106	118				34	46	58	70
72	84	96	108	120		12	24	36	48	60

Handout

Mit den *geraden* Zahlen zwischen 1 bis 49 zum magischen Quadrat ergänzen

			43			
		29	37	45		
	15	23	31	39	47	
1	9	17	25	33	41	49
	3	11	19	27	35	
		5	13	21		
			7			

Handout

Mit den *geraden* Zahlen zwischen 1 bis 81 zum magischen Quadrat ergänzen

				73				
			55	65	75			
		37	47	57	67	77		
	19	29	39	49	59	69	79	
1	11	21	31	41	51	61	71	81
	3	13	23	33	43	53	63	
		5	15	25	35	45		
			7	17	27			
				9				

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

Magisches Quadrat ungerader Seitenlänge

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

65

Magisches Quadrat ungerader Seitenlänge

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

65

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

65

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

65

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

65

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

65

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

Median in der Mitte

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

Komplementäre Symmetrie

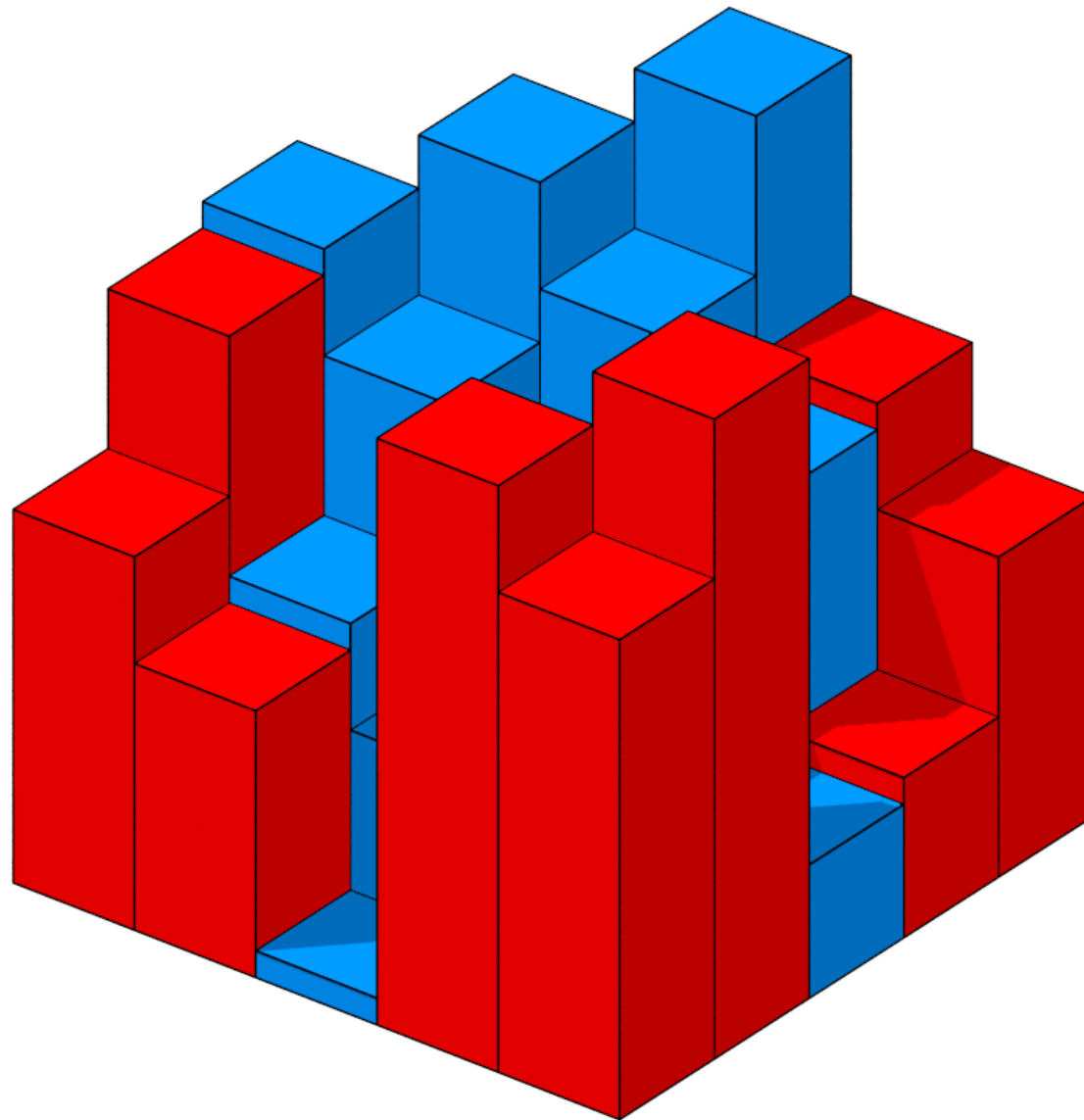
14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

Komplementäre Symmetrie

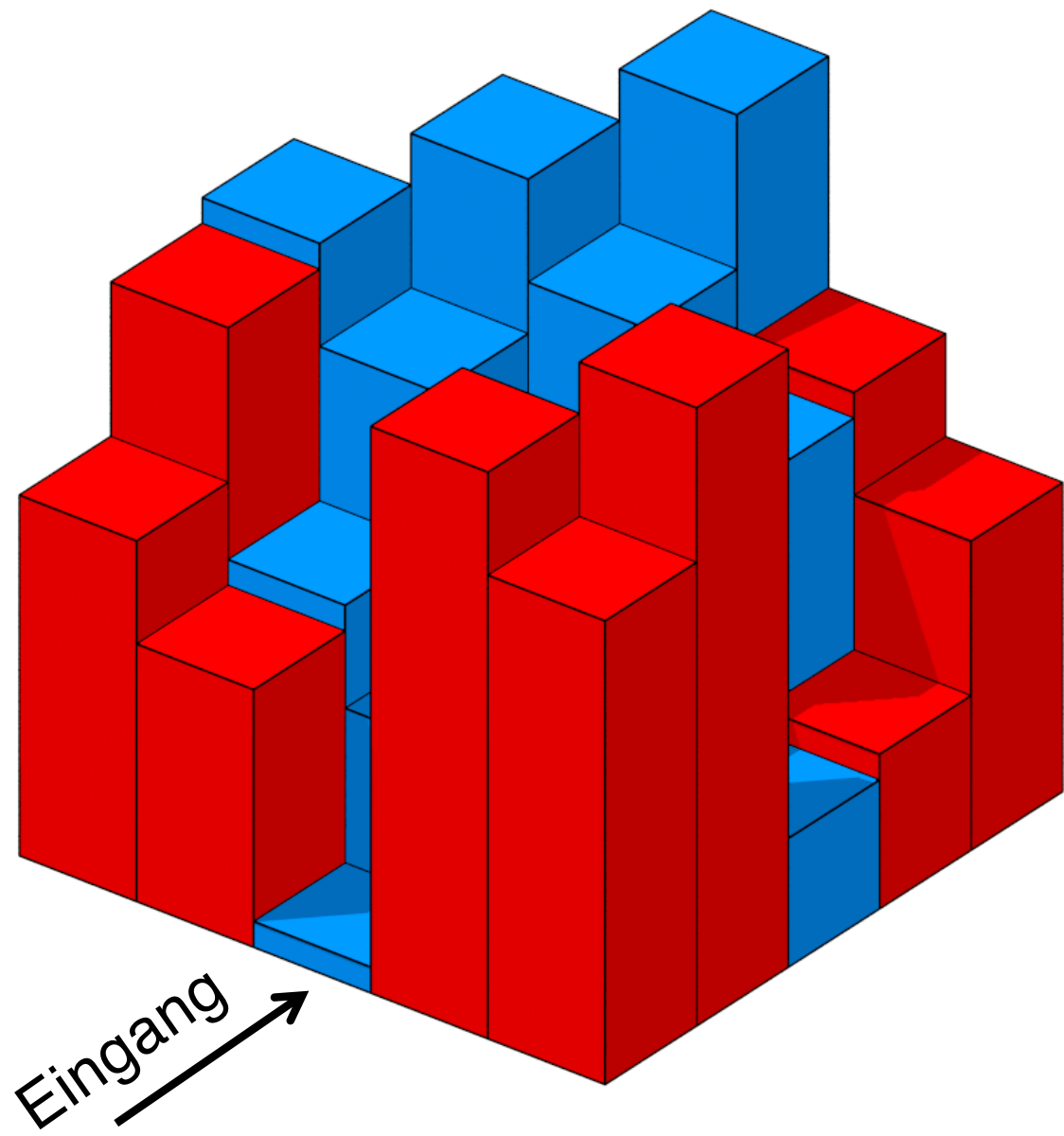
Eingang →

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

gerade / ungerade



Histogramm (unterhöht gezeichnet)



Eingang →

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

14	20	21	2	8
10	11	17	23	4
1	7	13	19	25
22	3	9	15	16
18	24	5	6	12

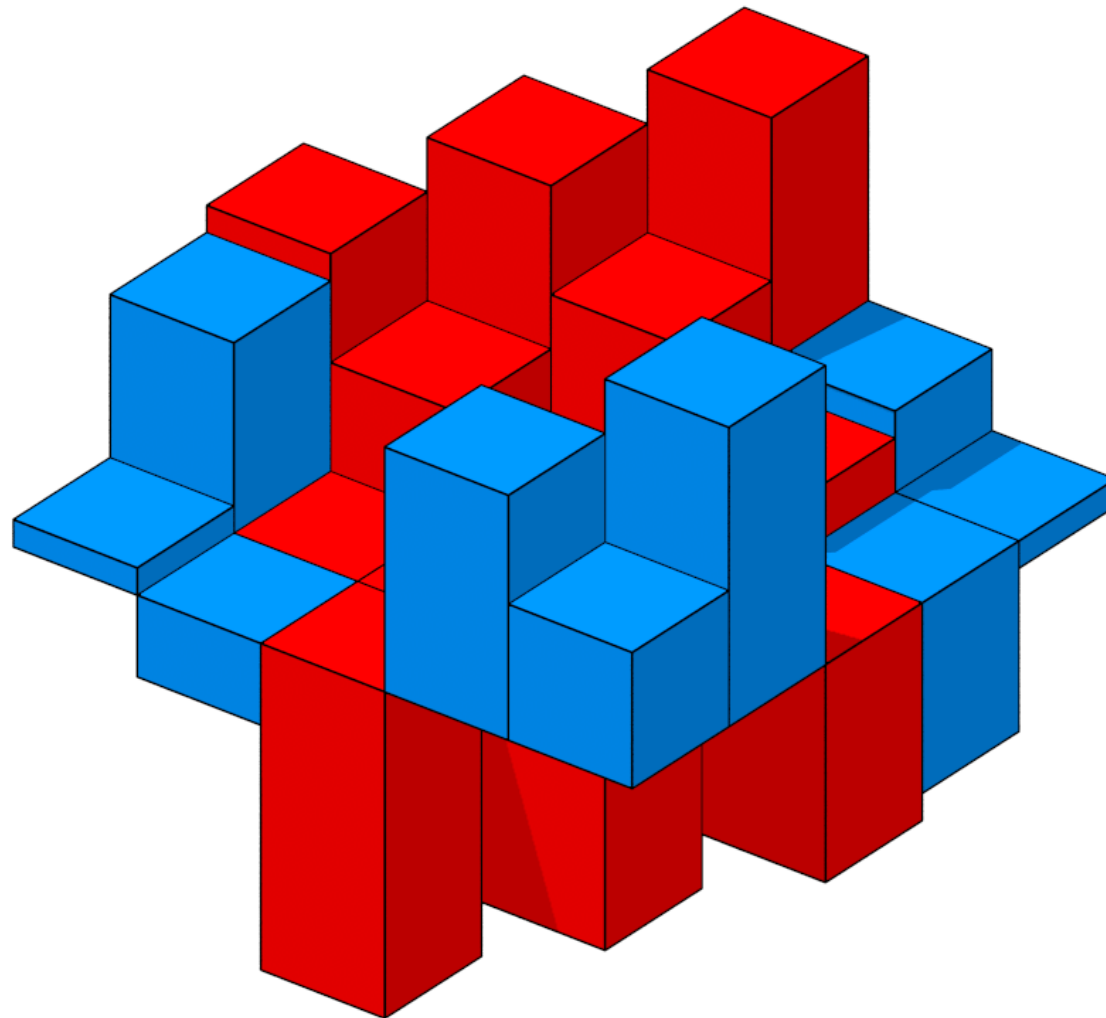
-13
→

1	7	8	-11	-5
-3	-2	4	10	-9
-12	-6	0	6	12
9	-10	-4	2	3
5	11	-8	-7	-1

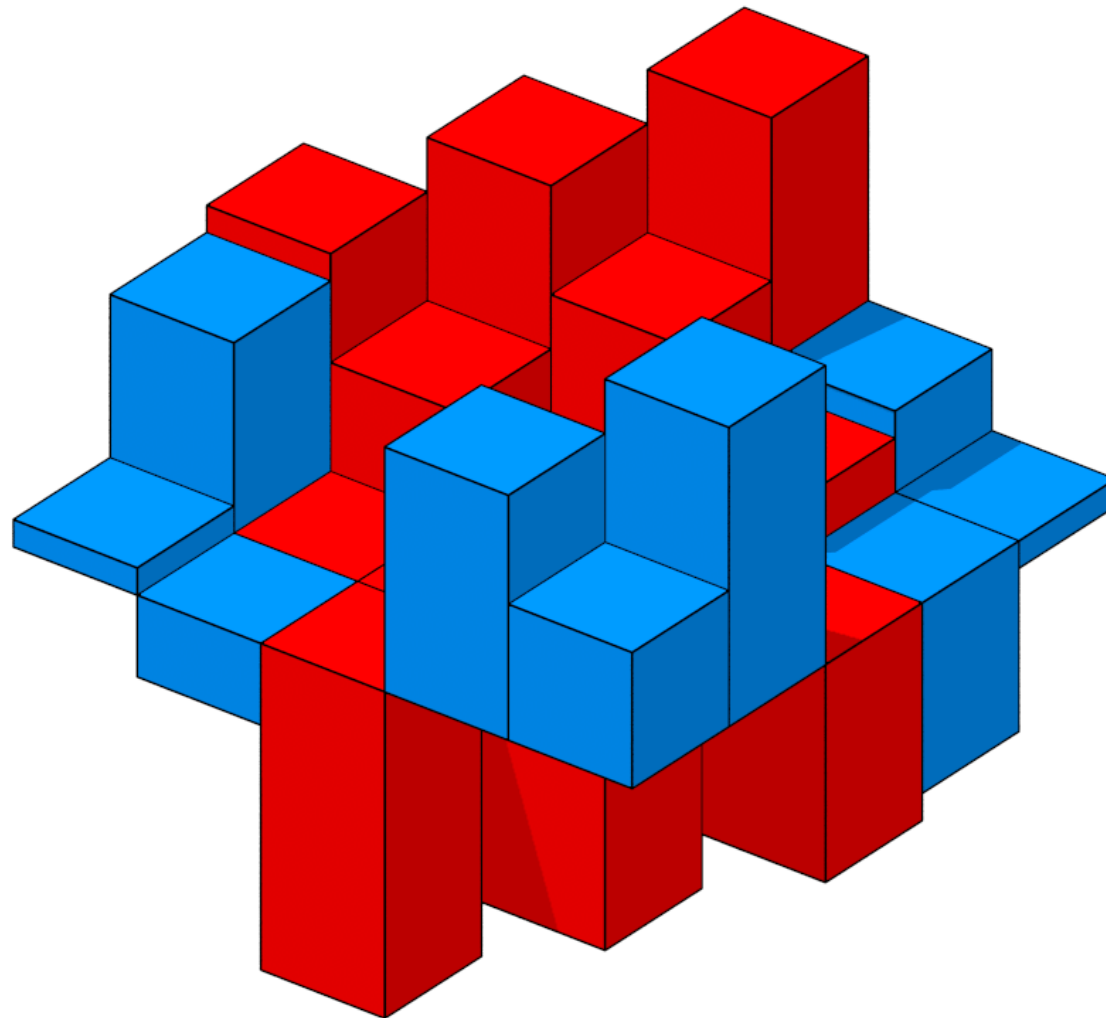
1	7	8	-11	-5
-3	-2	4	10	-9
-12	-6	0	6	12
9	-10	-4	2	3
5	11	-8	-7	-1

1	7	8	-11	-5	0
-3	-2	4	10	-9	0
-12	-6	0	6	12	0
9	-10	-4	2	3	0
5	11	-8	-7	-1	0

0 0 0 0 0 0 0



Histogramm



Punktsymmetrie im Raum

Konstruktion

				0
			0	
		0		
	0			
0				

Konstruktion

1				0
			0	1
		0	1	
	0	1		
0	1			

Konstruktion

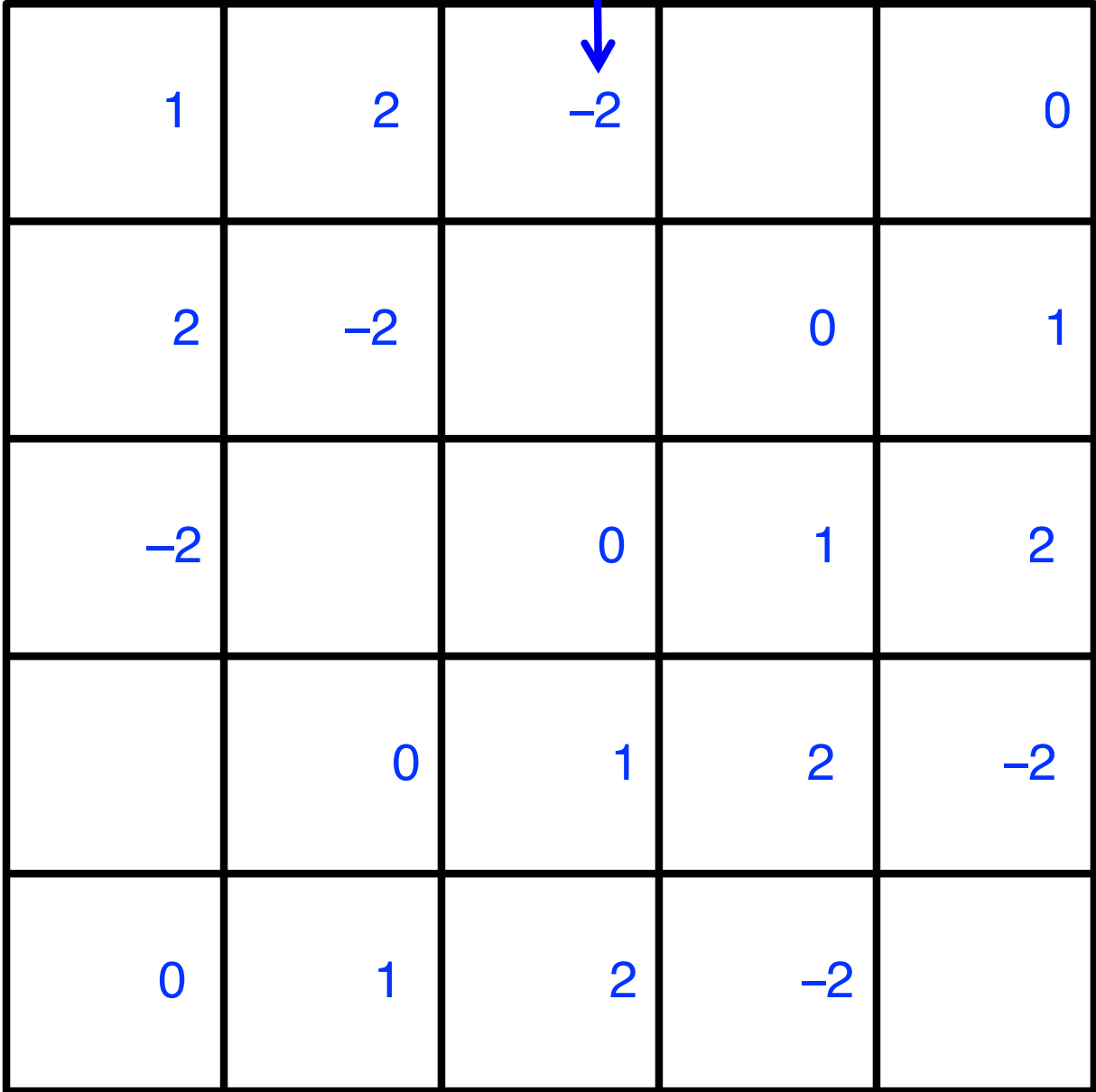
1	2			0
2			0	1
		0	1	2
	0	1	2	
0	1	2		

Konstruktion

1	2	-2		0
2	-2		0	1
-2		0	1	2
	0	1	2	-2
0	1	2	-2	

Konstruktion

$$\text{mods}(3,5) = -2$$



1	2	-2		0
2	-2		0	1
-2		0	1	2
	0	1	2	-2
0	1	2	-2	

Konstruktion

„positiv“



i	$\text{modp}(i, 5)$
-8	2
-7	3
-6	4
-5	0
-4	1
-3	2
-2	3
-1	4
0	0
1	1
2	2
3	3
4	4
5	0
6	1
7	2
8	3

„positiv“



i	$\text{modp}(i, 5)$
-8	2
-7	3
-6	4
-5	0
-4	1
-3	2
-2	3
-1	4
0	0
1	1
2	2
3	3
4	4
5	0
6	1
7	2
8	3

symmetrisch



i	$\text{mods}(i, 5)$
-8	2
-7	-2
-6	-1
-5	0
-4	1
-3	2
-2	-2
-1	-1
0	0
1	1
2	2
3	-2
4	-1
5	0
6	1
7	2
8	-2

„positiv“

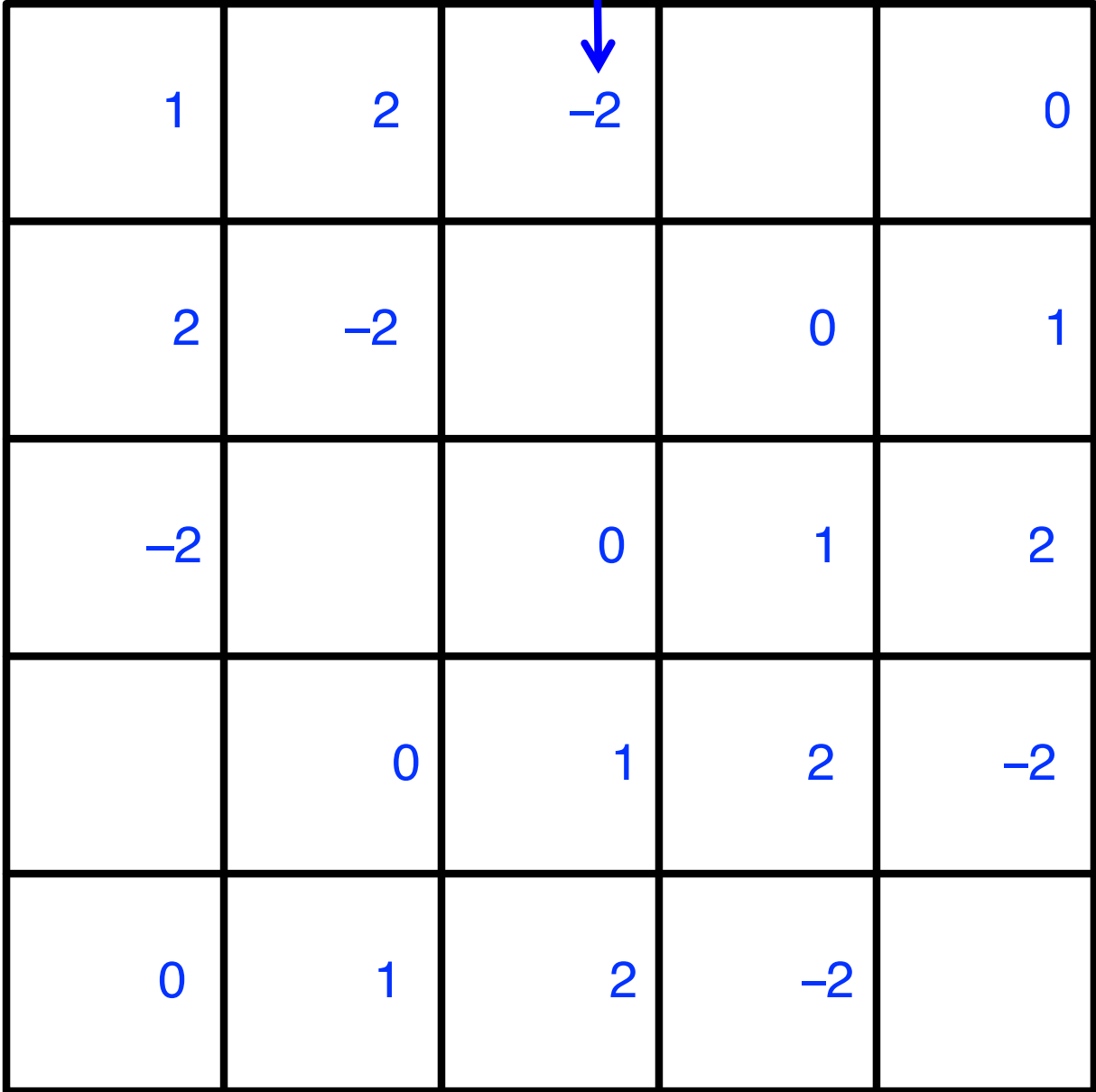
i	$\text{modp}(i, 5)$
-8	2
-7	3
-6	4
-5	0
-4	1
-3	2
-2	3
-1	4
0	0
1	1
2	2
3	3
4	4
5	0
6	1
7	2
8	3

symmetrisch

i	$\text{mods}(i, 5)$
-8	2
-7	-2
-6	-1
-5	0
-4	1
-3	2
-2	-2
-1	-1
0	0
1	1
2	2
3	-2
4	-1
5	0
6	1
7	2
8	-2



$$\text{mods}(3,5) = -2$$



1	2	-2		0
2	-2		0	1
-2		0	1	2
	0	1	2	-2
0	1	2	-2	

Konstruktion

$$\text{mods}(4,5) = -1$$



1	2	-2	-1	0
2	-2	-1	0	1
-2	-1	0	1	2
-1	0	1	2	-2
0	1	2	-2	-1

Konstruktion

1	2	-2	-1	0
2	-2	-1	0	1
-2	-1	0	1	2
-1	0	1	2	-2
0	1	2	-2	-1

0

0

0

0

0

0

0

0

0

0

0

0

0	1	2	-2	-1	0
2	0	-2	-1	0	1
-2	-1	0	0	1	2
-1	0	1	0	2	-2
0	1	2	-2	0	-1

Konstruktion

0	1	1	2	2	-2	-2	-1	-1	0
-1	2	0	-2	1	-1	2	0	-2	1
-2	-2	-1	-1	0	0	1	1	2	2
2	-1	-2	0	-1	1	0	2	1	-2
1	0	2	1	-2	2	-1	-2	0	-1

Konstruktion

$0 \times 5 + 1$	$1 \times 5 + 2$	$2 \times 5 - 2$	$-2 \times 5 - 1$	$-1 \times 5 + 0$
$-1 \times 5 + 2$	$0 \times 5 - 2$	$1 \times 5 - 1$	$2 \times 5 + 0$	$-2 \times 5 + 1$
$-2 \times 5 - 2$	$-1 \times 5 - 1$	$0 \times 5 + 0$	$1 \times 5 + 1$	$2 \times 5 + 2$
$2 \times 5 - 1$	$-2 \times 5 + 0$	$-1 \times 5 + 1$	$0 \times 5 + 2$	$1 \times 5 - 2$
$1 \times 5 + 0$	$2 \times 5 + 1$	$-2 \times 5 + 2$	$-1 \times 5 - 2$	$0 \times 5 - 1$

Positionssystem auf der Basis 5

$0 \times 5 + 1$	$1 \times 5 + 2$	$2 \times 5 - 2$	$-2 \times 5 - 1$	$-1 \times 5 + 0$	0
$-1 \times 5 + 2$	$0 \times 5 - 2$	$1 \times 5 - 1$	$2 \times 5 + 0$	$-2 \times 5 + 1$	0
$-2 \times 5 - 2$	$-1 \times 5 - 1$	$0 \times 5 + 0$	$1 \times 5 + 1$	$2 \times 5 + 2$	0
$2 \times 5 - 1$	$-2 \times 5 + 0$	$-1 \times 5 + 1$	$0 \times 5 + 2$	$1 \times 5 - 2$	0
$1 \times 5 + 0$	$2 \times 5 + 1$	$-2 \times 5 + 2$	$-1 \times 5 - 2$	$0 \times 5 - 1$	0

0

0

0

0

0

0

0

1	7	8	-11	-5
-3	-2	4	10	-9
-12	-6	0	6	12
9	-10	-4	2	3
5	11	-8	-7	-1

0

0

0

0

0

0

0

0

0

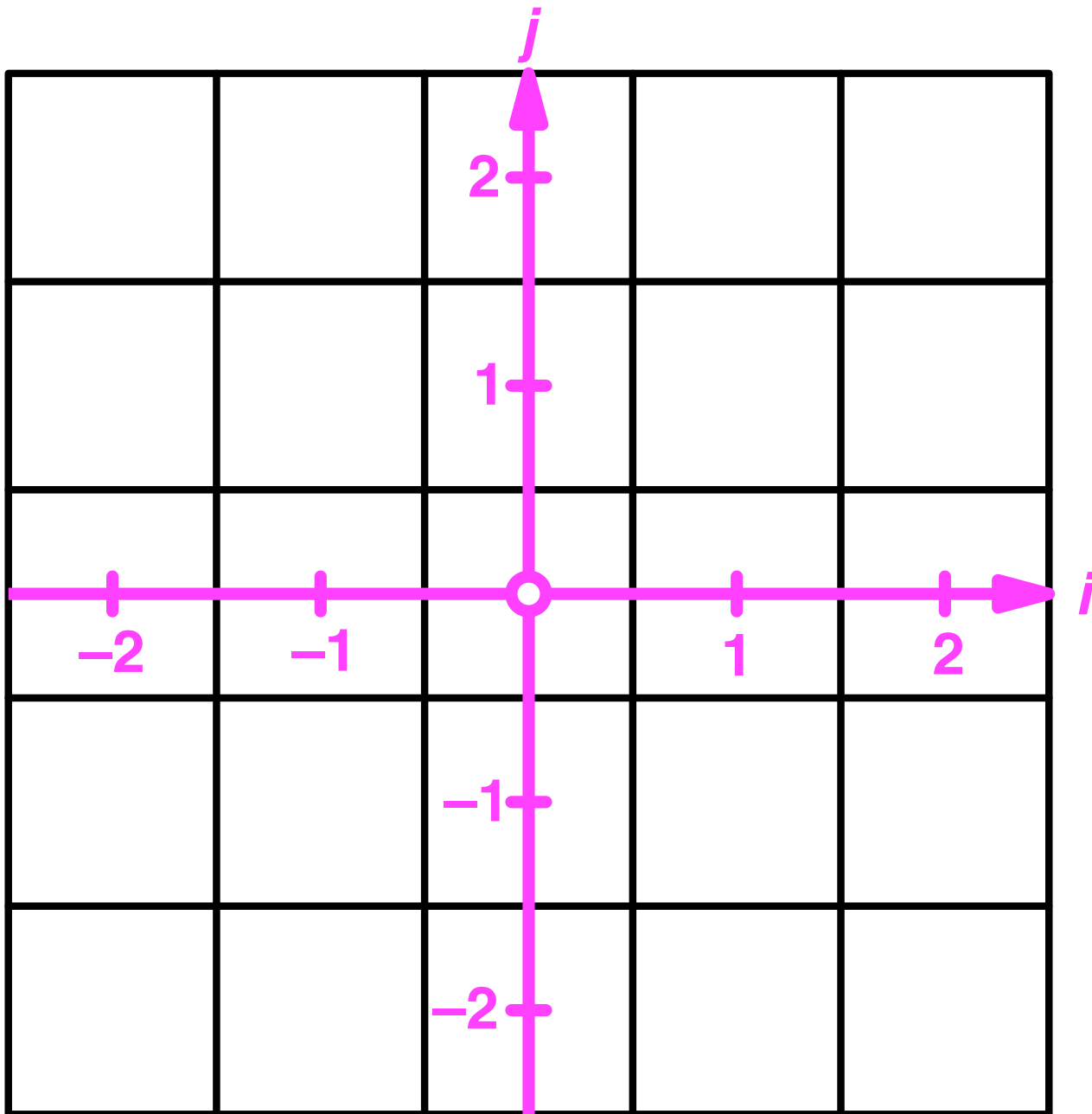
0

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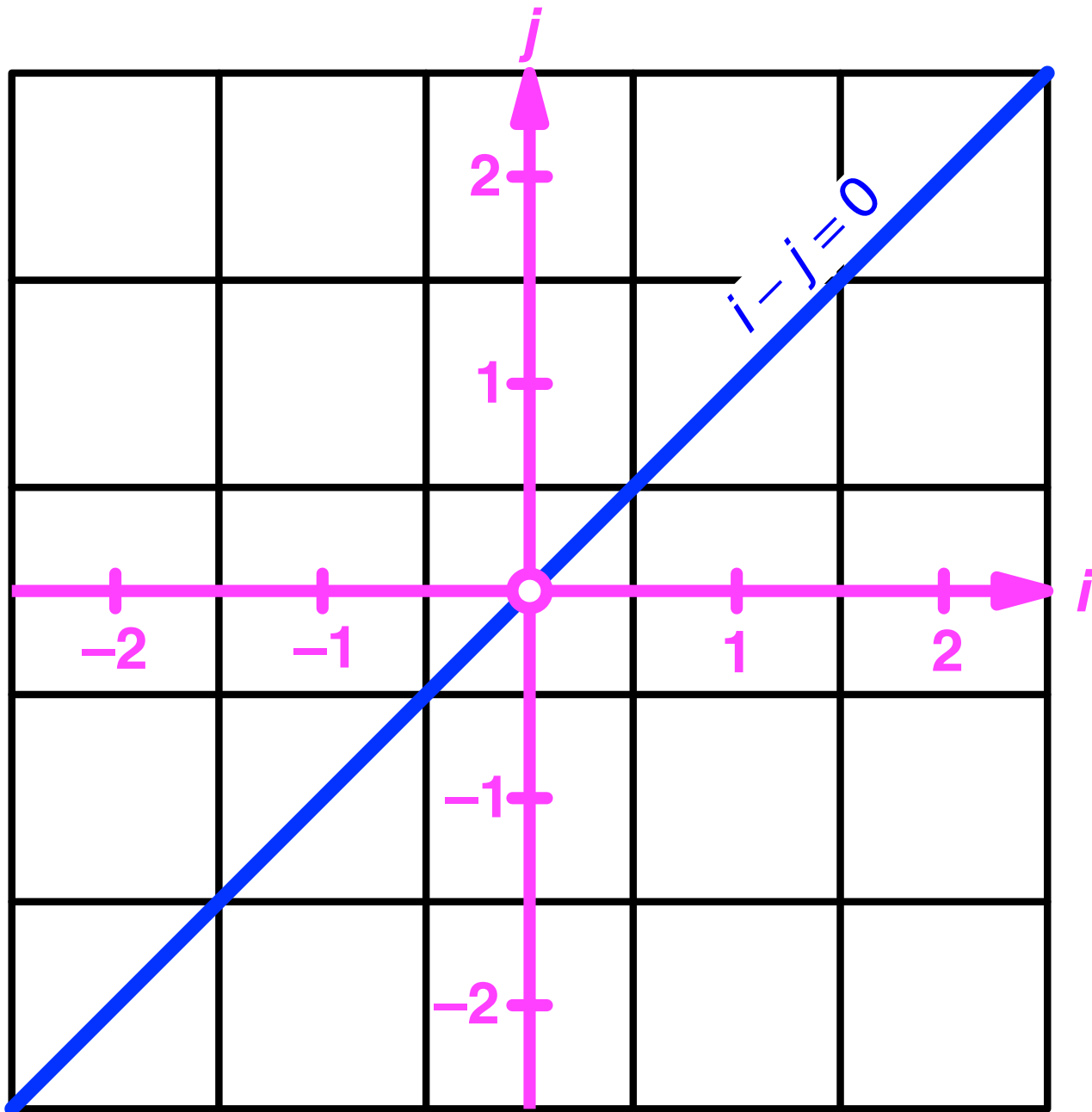
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$m_{-2,2}$	$m_{-1,2}$	$m_{0,2}$	$m_{1,2}$	$m_{2,2}$
$m_{-2,1}$	$m_{-1,1}$	$m_{0,1}$	$m_{1,1}$	$m_{2,1}$
$m_{-2,0}$	$m_{-1,0}$	$m_{0,0}$	$m_{1,0}$	$m_{2,0}$
$m_{-2,-1}$	$m_{-1,-1}$	$m_{0,-1}$	$m_{1,-1}$	$m_{2,-1}$
$m_{-2,-2}$	$m_{-1,-2}$	$m_{0,-2}$	$m_{1,-2}$	$m_{2,-2}$

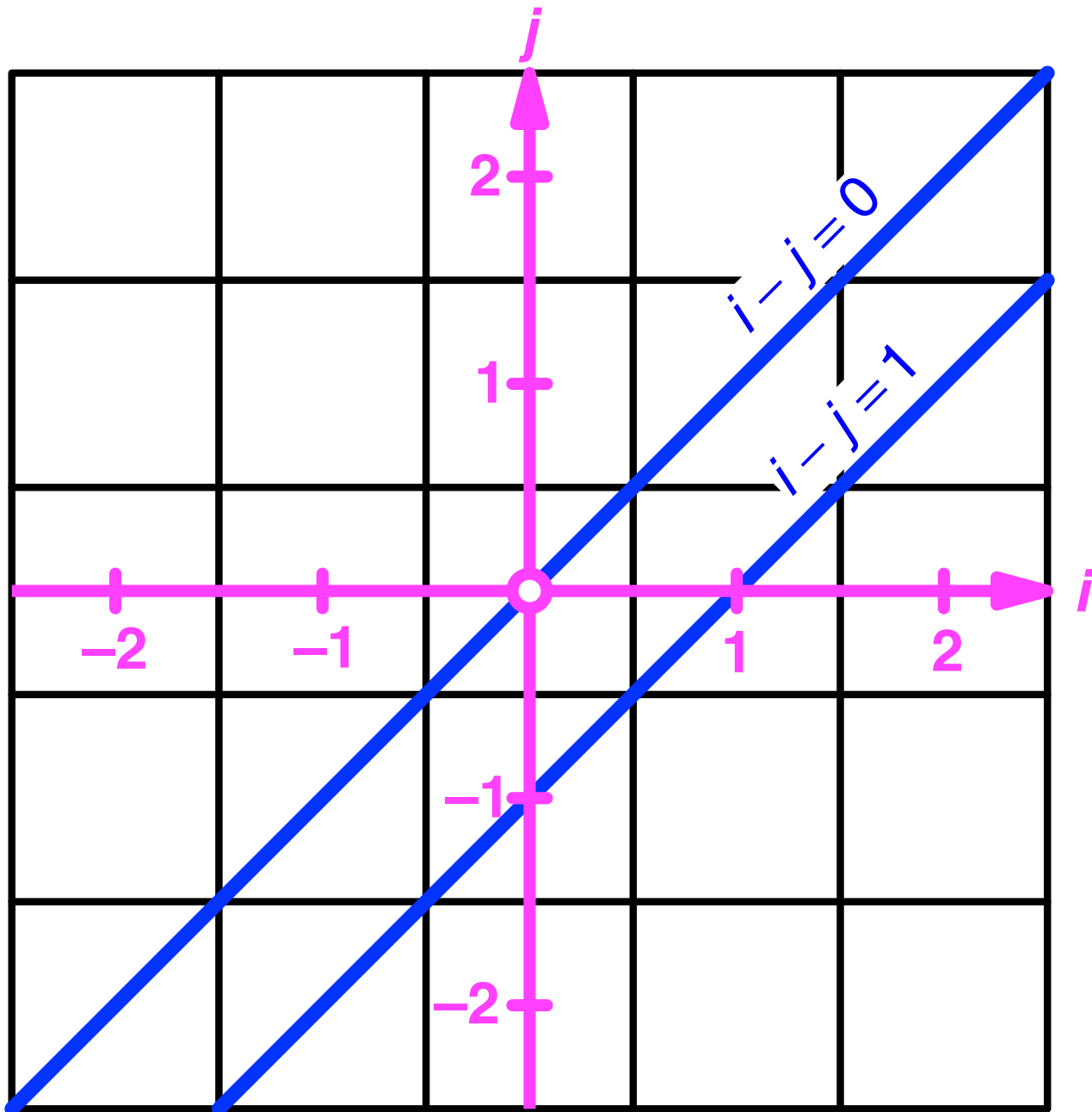
Zentrische kartesische Indizierung



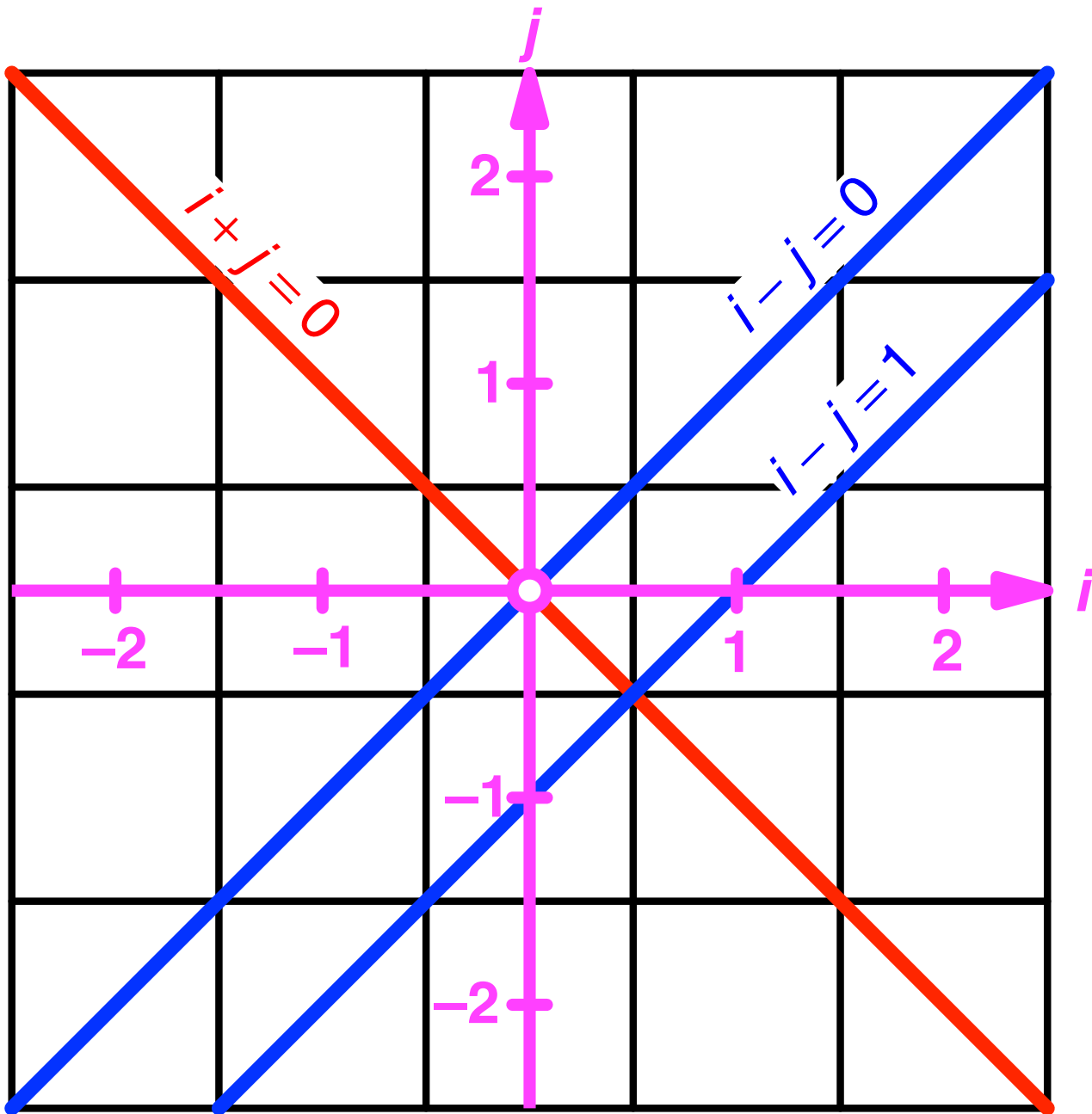
Zentrische kartesische Indizierung



Geradengleichung



Geradengleichung



Geradengleichung

$$m_{i,j} = \underbrace{\text{mods}((i+j),5)}_{\text{Fünfer}} \times 5 + \underbrace{\text{mods}((i-j),5)}_{\text{Einer}} \quad i, j \in \{-2, \dots, 2\}$$

Gibt ein magisches Quadrat der Seitenlänge 5

$$m_{i,j} = \underbrace{\text{mods}((i+j), 5)}_{\text{Fünfer}} \times 5 + \underbrace{\text{mods}((i-j), 5)}_{\text{Einer}} \quad i, j \in \{-2, \dots, 2\}$$

Gibt ein magisches Quadrat der Seitenlänge 5

$$m_{i,j} = \underbrace{\text{mods}((i+j), u)}_{u\text{-er}} \times u + \underbrace{\text{mods}((i-j), u)}_{\text{Einer}} \quad i, j \in \left\{-\frac{u-1}{2}, \dots, \frac{u-1}{2}\right\}$$

Gibt ein magisches Quadrat der ungeraden Seitenlänge u

Beispiel: $u = 15$

1	17	33	49	65	81	97	98	-111	-95	-79	-63	-47	-31	-15
-13	3	19	35	51	67	68	84	100	-109	-93	-77	-61	-45	-29
-27	-11	5	21	37	38	54	70	86	102	-107	-91	-75	-59	-43
-41	-25	-9	7	8	24	40	56	72	88	104	-105	-89	-73	-57
-55	-39	-23	-22	-6	10	26	42	58	74	90	106	-103	-87	-71
-69	-53	-52	-36	-20	-4	12	28	44	60	76	92	108	-101	-85
-83	-82	-66	-50	-34	-18	-2	14	30	46	62	78	94	110	-99
-112	-96	-80	-64	-48	-32	-16	0	16	32	48	64	80	96	112
99	-110	-94	-78	-62	-46	-30	-14	2	18	34	50	66	82	83
85	101	-108	-92	-76	-60	-44	-28	-12	4	20	36	52	53	69
71	87	103	-106	-90	-74	-58	-42	-26	-10	6	22	23	39	55
57	73	89	105	-104	-88	-72	-56	-40	-24	-8	-7	9	25	41
43	59	75	91	107	-102	-86	-70	-54	-38	-37	-21	-5	11	27
29	45	61	77	93	109	-100	-84	-68	-67	-51	-35	-19	-3	13
15	31	47	63	79	95	111	-98	-97	-81	-65	-49	-33	-17	-1

Beispiel: $u = 15$

Eingang
→

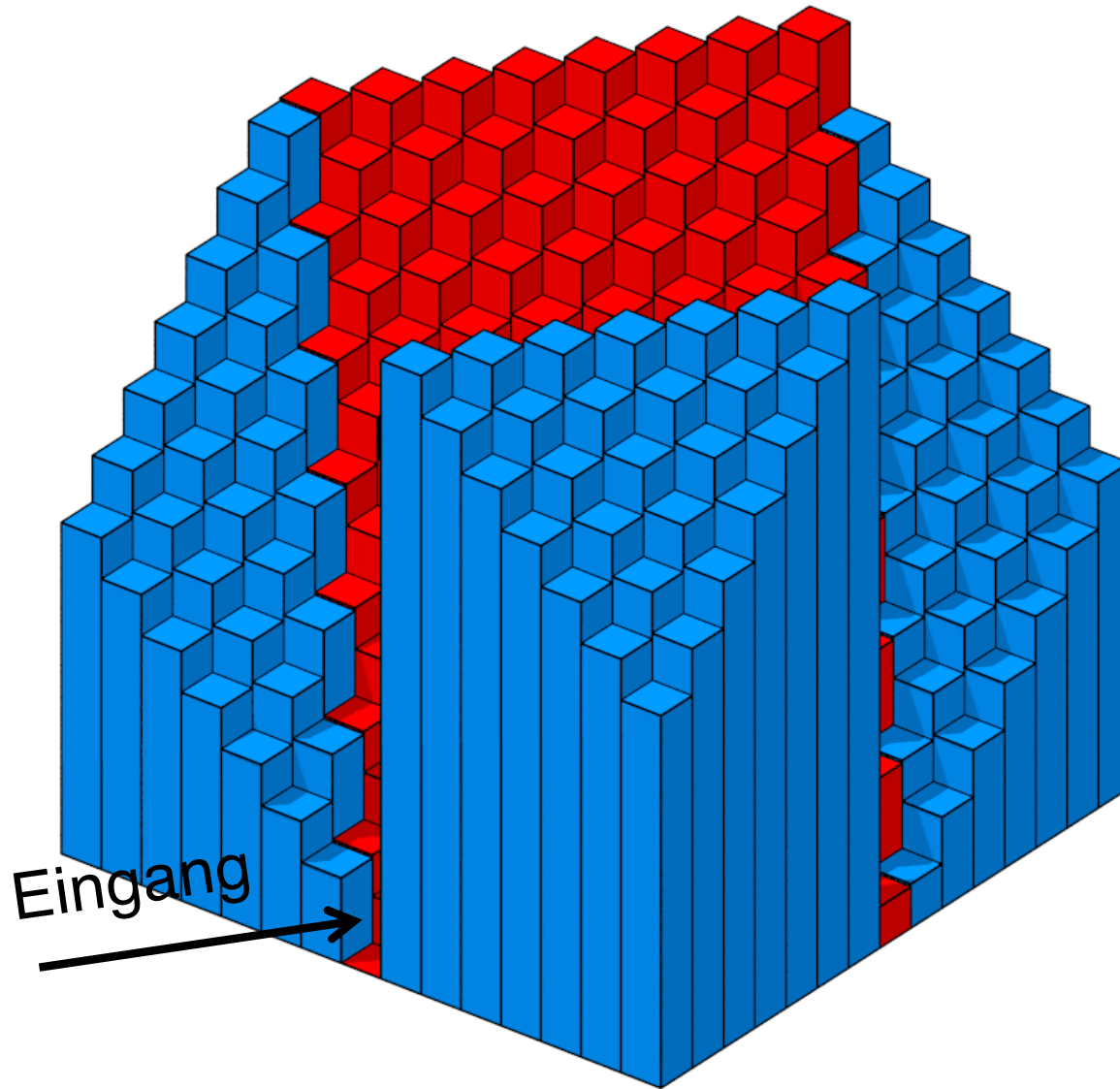
113	129	145	161	177	193	209	210	1	17	33	49	65	81	97
99	115	131	147	163	179	180	196	212	3	19	35	51	67	83
85	101	117	133	149	150	166	182	198	214	5	21	37	53	69
71	87	103	119	120	136	152	168	184	200	216	7	23	39	55
57	73	89	90	106	122	138	154	170	186	202	218	9	25	41
43	59	60	76	92	108	124	140	156	172	188	204	220	11	27
29	30	46	62	78	94	110	126	142	158	174	190	206	222	13
0	16	32	48	64	80	96	112	128	144	160	176	192	208	224
211	2	18	34	50	66	82	98	114	130	146	162	178	194	195
197	213	4	20	36	52	68	84	100	116	132	148	164	165	181
183	199	215	6	22	38	54	70	86	102	118	134	135	151	167
169	185	201	217	8	24	40	56	72	88	104	105	121	137	153
155	171	187	203	219	10	26	42	58	74	75	91	107	123	139
141	157	173	189	205	221	12	28	44	45	61	77	93	109	125
127	143	159	175	191	207	223	14	15	31	47	63	79	95	111

Beispiel: $u = 15$

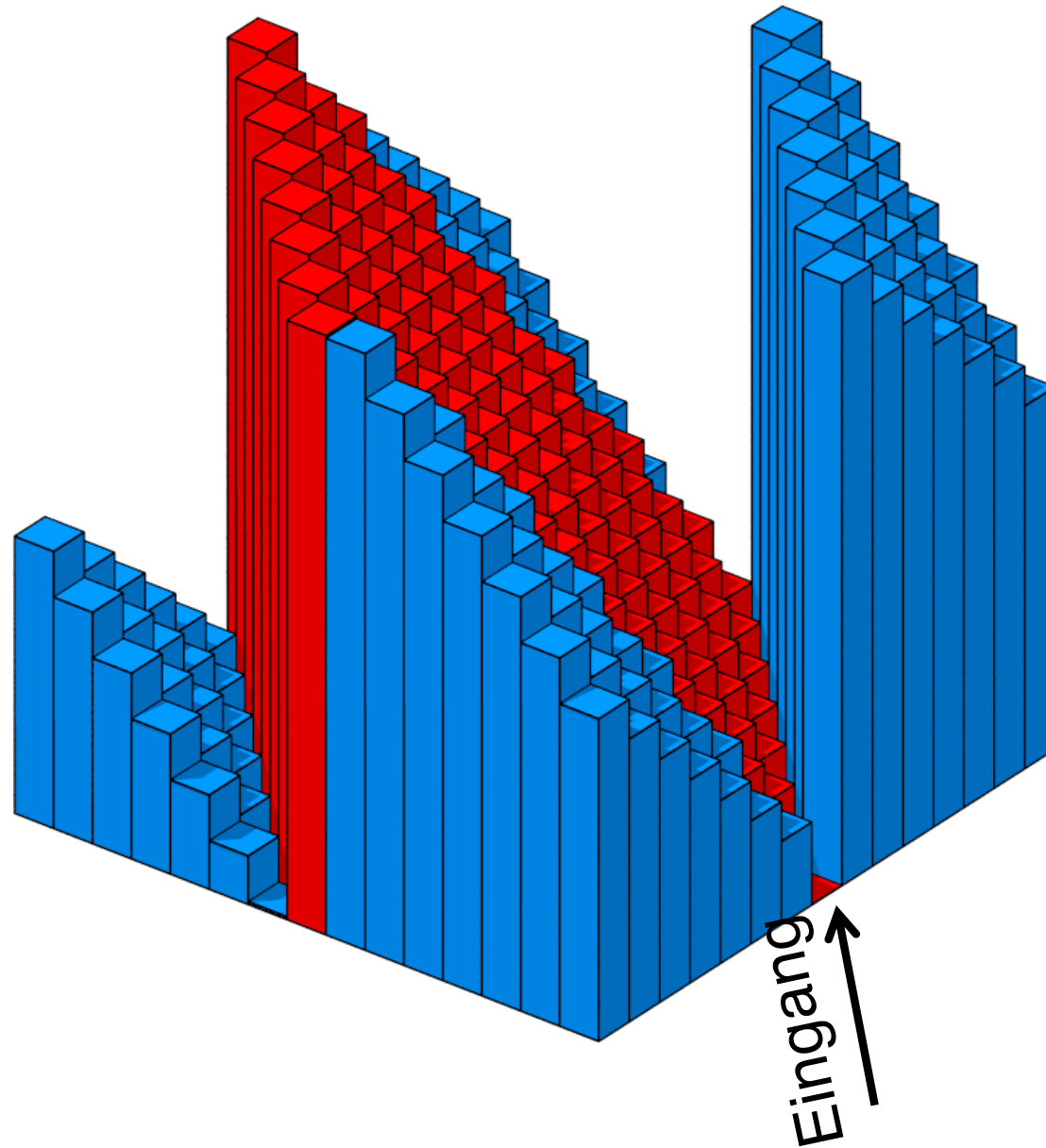
Eingang
↓

113	129	145	161	177	193	209	210	1	17	33	49	65	81	97
99	115	131	147	163	179	180	196	212	3	19	35	51	67	83
85	101	117	133	149	150	166	182	198	214	5	21	37	53	69
71	87	103	119	120	136	152	168	184	200	216	7	23	39	55
57	73	89	90	106	122	138	154	170	186	202	218	9	25	41
43	59	60	76	92	108	124	140	156	172	188	204	220	11	27
29	30	46	62	78	94	110	126	142	158	174	190	206	222	13
0	16	32	48	64	80	96	112	128	144	160	176	192	208	224
211	2	18	34	50	66	82	98	114	130	146	162	178	194	195
197	213	4	20	36	52	68	84	100	116	132	148	164	165	181
183	199	215	6	22	38	54	70	86	102	118	134	135	151	167
169	185	201	217	8	24	40	56	72	88	104	105	121	137	153
155	171	187	203	219	10	26	42	58	74	75	91	107	123	139
141	157	173	189	205	221	12	28	44	45	61	77	93	109	125
127	143	159	175	191	207	223	14	15	31	47	63	79	95	111

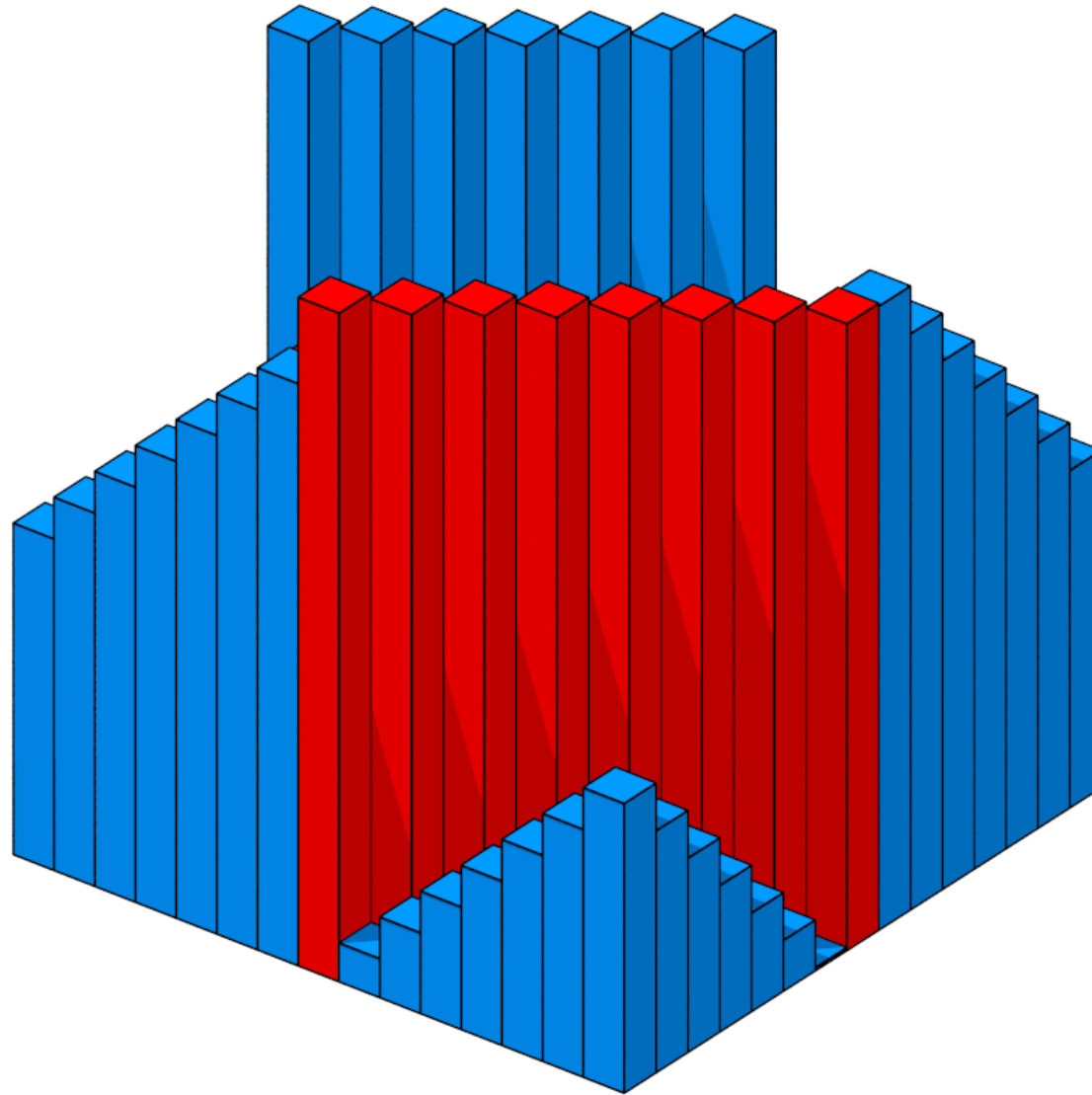
Beispiel: $u = 15$



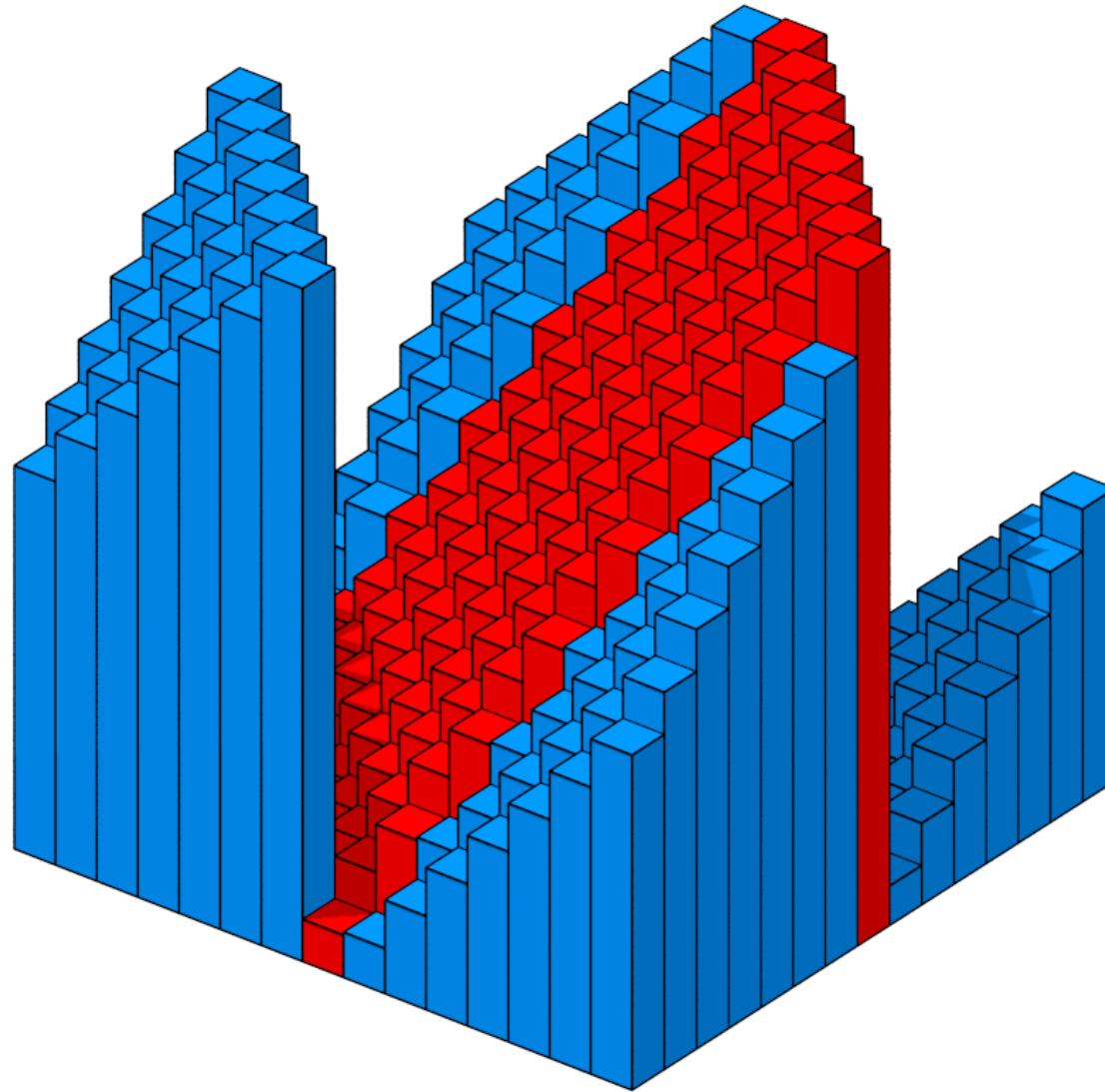
Beispiel: $u = 15$



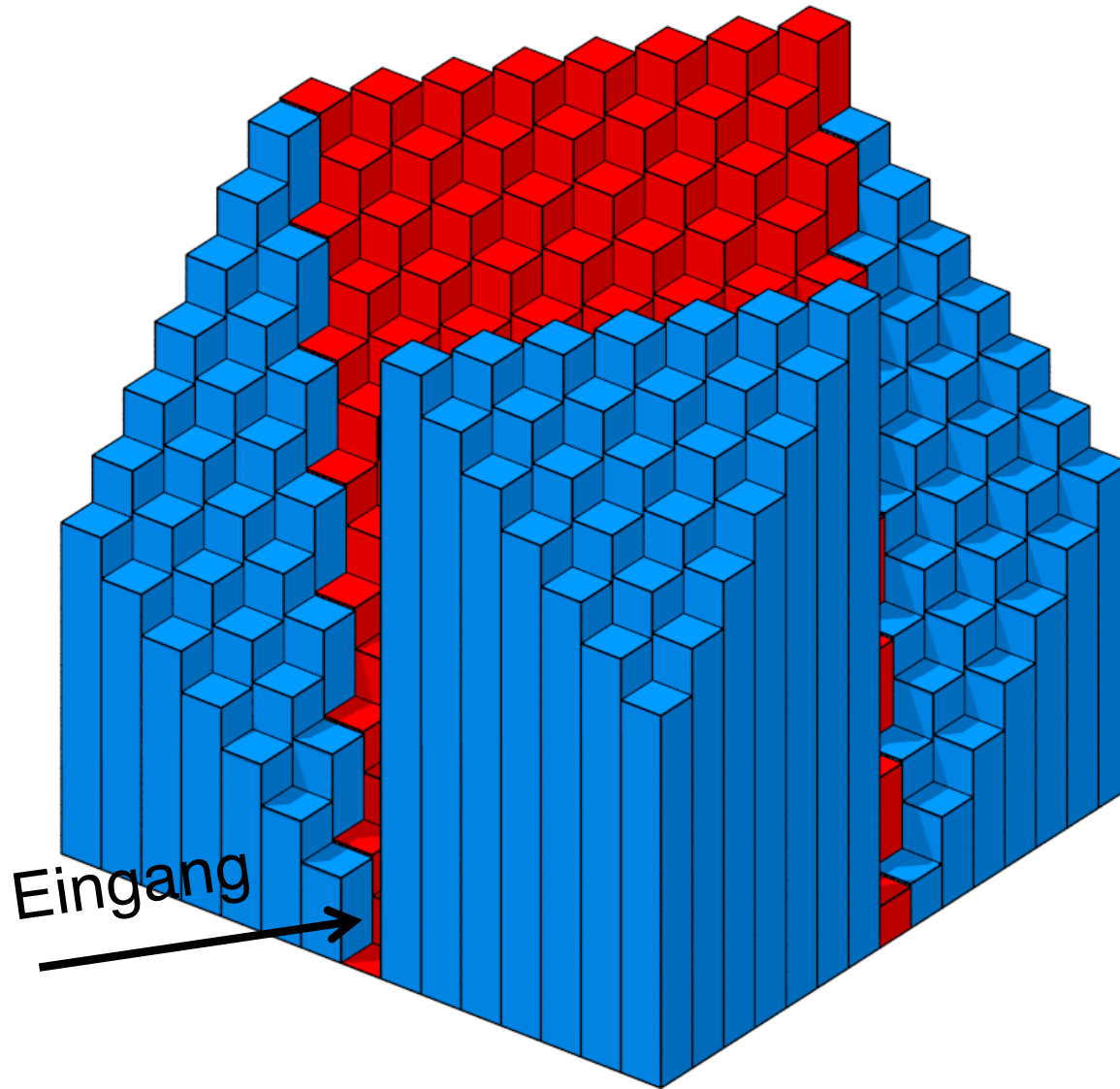
Beispiel: $u = 15$



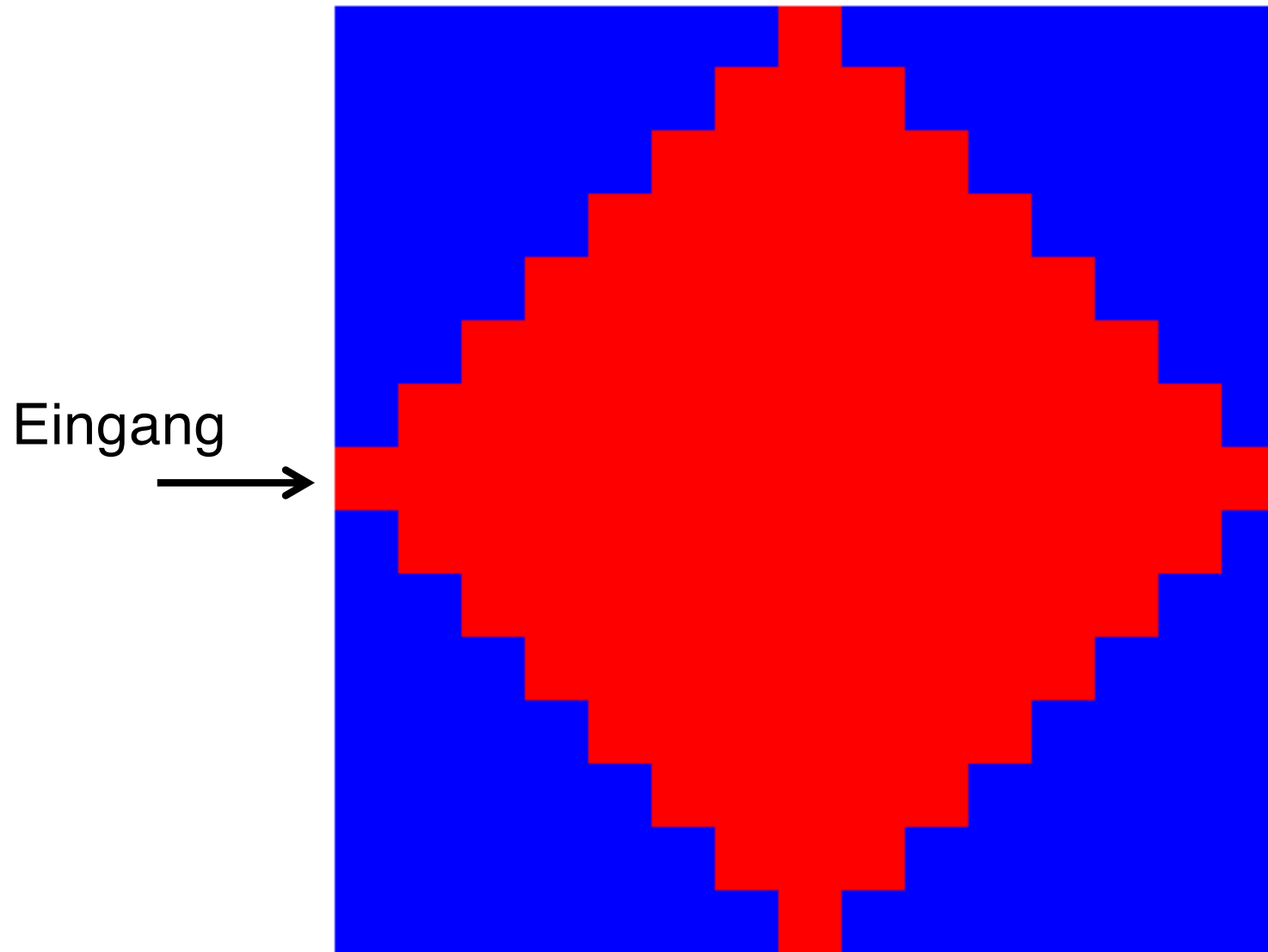
Beispiel: $u = 15$



Beispiel: $u = 15$



Beispiel: $u = 15$



gerade / ungerade

Negative Zahlen *ohne* sichtbare Minuszeichen

Zwischenspiel

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Zwischenspiel

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Zwischenspiel

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Zwischenspiel

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2



Das ist des Pudels Kern

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Beispiele:

daddbe =

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Beispiele:

$$\text{daddbe} = d \times 5^5 + a \times 5^4 + d \times 5^3 + d \times 5^2 + b \times 5^1 + e \times 5^0$$

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Beispiele:

$$\begin{aligned} \text{daddbe} &= d \times 5^5 + a \times 5^4 + d \times 5^3 + d \times 5^2 + b \times 5^1 + e \times 5^0 \\ &= 1 \times 3125 + (-2) \times 625 + 1 \times 125 + 1 \times 25 + (-1) \times 5 + (-2) \times 1 \end{aligned}$$

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Beispiele:

$$\begin{aligned} \text{daddbe} &= d \times 5^5 + a \times 5^4 + d \times 5^3 + d \times 5^2 + b \times 5^1 + e \times 5^0 \\ &= 1 \times 3125 + (-2) \times 625 + 1 \times 125 + 1 \times 25 + (-1) \times 5 + (-2) \times 1 \\ &= 2022 \end{aligned}$$

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Beispiele:

$$\begin{aligned} \text{daddbe} &= d \times 5^5 + a \times 5^4 + d \times 5^3 + d \times 5^2 + b \times 5^1 + e \times 5^0 \\ &= 1 \times 3125 + (-2) \times 625 + 1 \times 125 + 1 \times 25 + (-1) \times 5 + (-2) \times 1 \\ &= 2022 \end{aligned}$$

bebbda

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Beispiele:

$$\begin{aligned} \text{daddbe} &= d \times 5^5 + a \times 5^4 + d \times 5^3 + d \times 5^2 + b \times 5^1 + e \times 5^0 \\ &= 1 \times 3125 + (-2) \times 625 + 1 \times 125 + 1 \times 25 + (-1) \times 5 + (-2) \times 1 \\ &= 2022 \end{aligned}$$

$$\text{bebbda} = b \times 5^5 + e \times 5^4 + b \times 5^3 + b \times 5^2 + d \times 5^1 + a \times 5^0$$

Negative Zahlen *ohne* sichtbare Minuszeichen

Positionssystem auf Basis 5 (exemplarisch)

Ziffernsymbole: a , b , c , d , e

Wert: -2 , -1 , 0 , 1 , 2

Beispiele:

$$\begin{aligned}daddbe &= d \times 5^5 + a \times 5^4 + d \times 5^3 + d \times 5^2 + b \times 5^1 + e \times 5^0 \\ &= 1 \times 3125 + (-2) \times 625 + 1 \times 125 + 1 \times 25 + (-1) \times 5 + (-2) \times 1 \\ &= 2022\end{aligned}$$

$$\begin{aligned}bebbda &= b \times 5^5 + e \times 5^4 + b \times 5^3 + b \times 5^2 + d \times 5^1 + a \times 5^0 \\ &= (-1) \times 3125 + 2 \times 625 + (-1) \times 125 + (-1) \times 25 + 1 \times 5 + (-2) \times 1 \\ &= -2022\end{aligned}$$

Beispiele:

1	7	8	-11	-5
-3	-2	4	10	-9
-12	-6	0	6	12
9	-10	-4	2	3
5	11	-8	-7	-1

Beispiele:

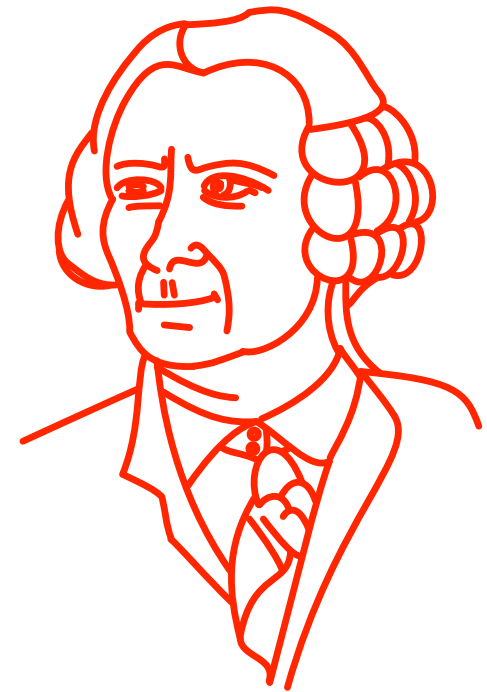
cd	de	ea	ab	bc
be	ca	db	ec	ad
aa	bb	cc	dd	ee
eb	ac	bd	ce	da
dc	ed	ae	ba	cb

Orthogonale lateinische Quadrate

Euler, Leonhard (1782) : E 530

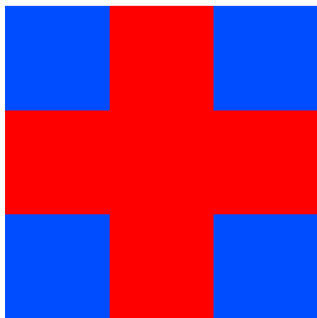
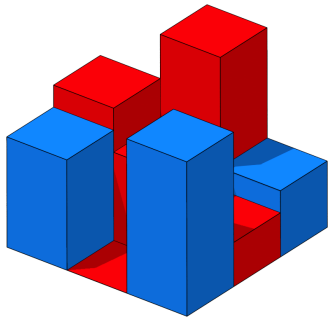
Recherches sur une nouvelle espèce de quarrés magiques

Vlissingen 1782 - Opera I 7, p. 291-392.



Verknüpfung

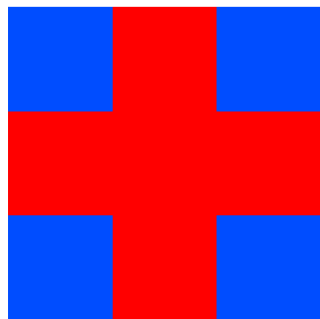
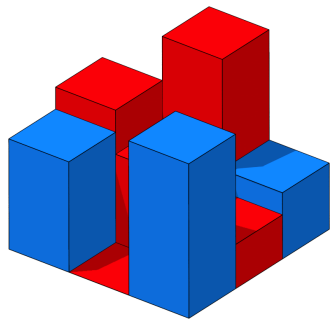
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0	4	8
7	2	3



5	6	1
0	4	8
7	2	3

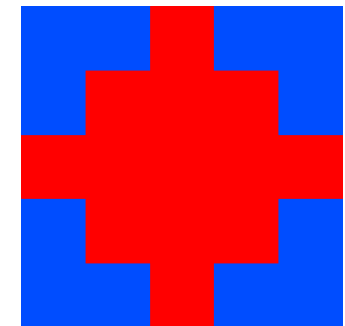
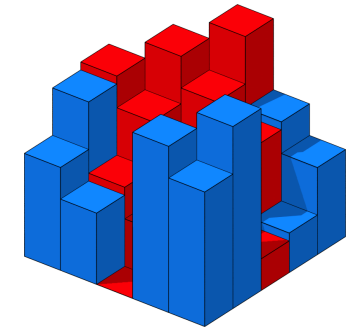
Verknüpfung

5	6	1
0	4	8
7	2	3



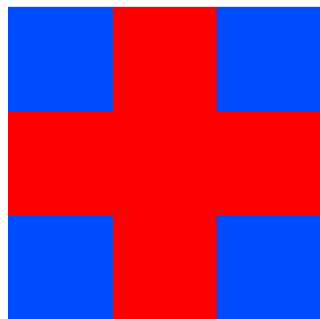
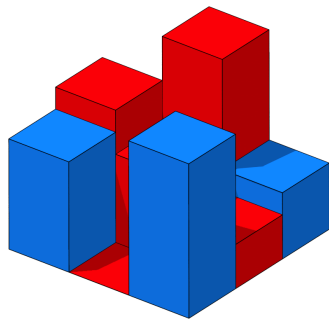
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0	6	12	18	24
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17	23	4	5	11

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21	2	8	14	15
17	23	4	5	11



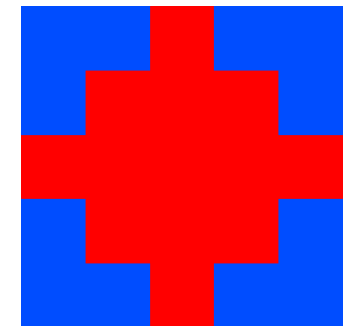
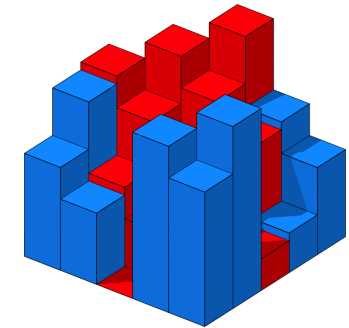
Verknüpfung

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0	4	8
7	2	3



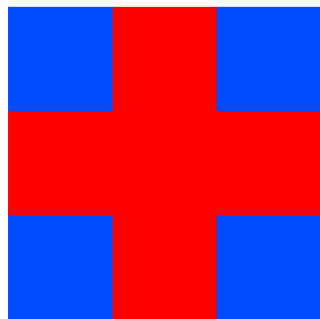
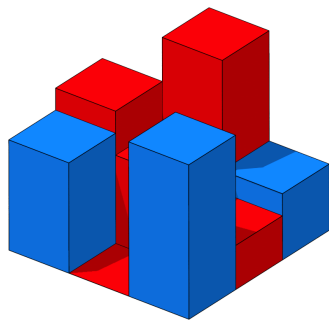
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21	21	21	2	2	2	8	8	8	14	14	14	15	15	15
21	21	21	2	2	2	8	8	8	14	14	14	15	15	15
17	17	17	23	23	23	4	4	4	5	5	5	11	11	11
17	17	17	23	23	23	4	4	4	5	5	5	11	11	11
17	17	17	23	23	23	4	4	4	5	5	5	11	11	11

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0	6	12	18	24
21	2	8	14	15
17	23	4	5	11



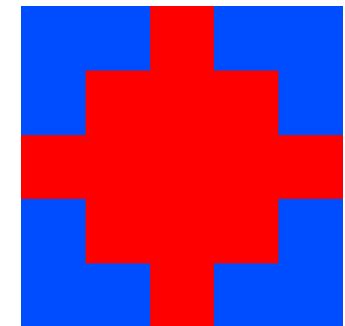
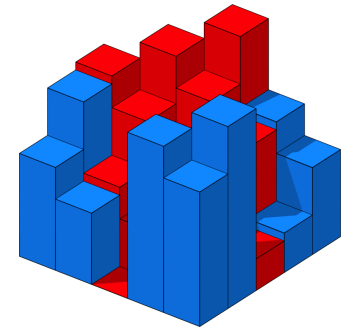
Verknüpfung

5	6	1
0	4	8
7	2	3



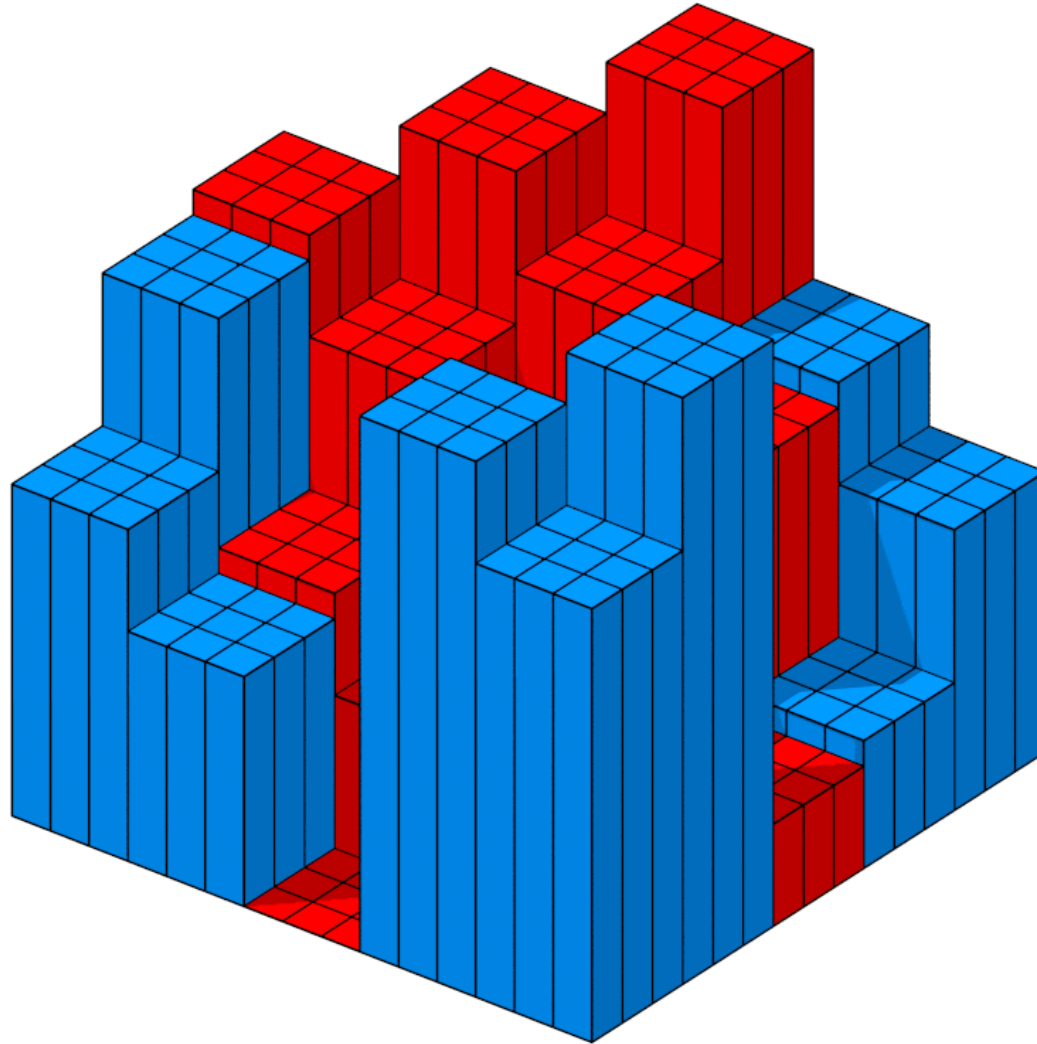
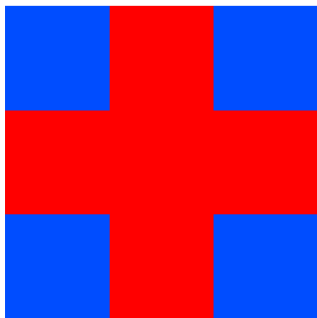
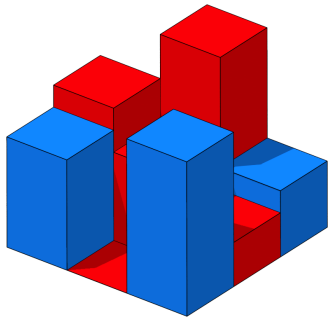
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117	117	117	171	171	171	180	180	180	9	9	9	63	63	63
81	81	81	90	90	90	144	144	144	198	198	198	27	27	27
81	81	81	90	90	90	144	144	144	198	198	198	27	27	27
81	81	81	90	90	90	144	144	144	198	198	198	27	27	27
0	0	0	54	54	54	108	108	108	162	162	162	216	216	216
0	0	0	54	54	54	108	108	108	162	162	162	216	216	216
0	0	0	54	54	54	108	108	108	162	162	162	216	216	216
189	189	189	18	18	18	72	72	72	126	126	126	135	135	135
189	189	189	18	18	18	72	72	72	126	126	126	135	135	135
189	189	189	18	18	18	72	72	72	126	126	126	135	135	135
153	153	153	207	207	207	36	36	36	45	45	45	99	99	99
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153	153	153	207	207	207	36	36	36	45	45	45	99	99	99

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17	23	4	5	11

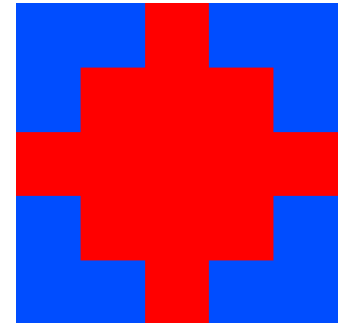
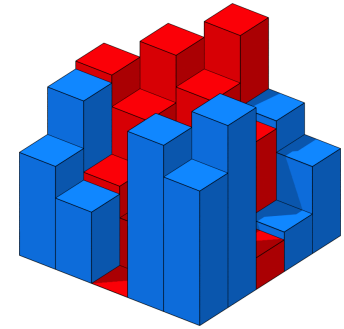


Verknüpfung

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0	4	8
7	2	3

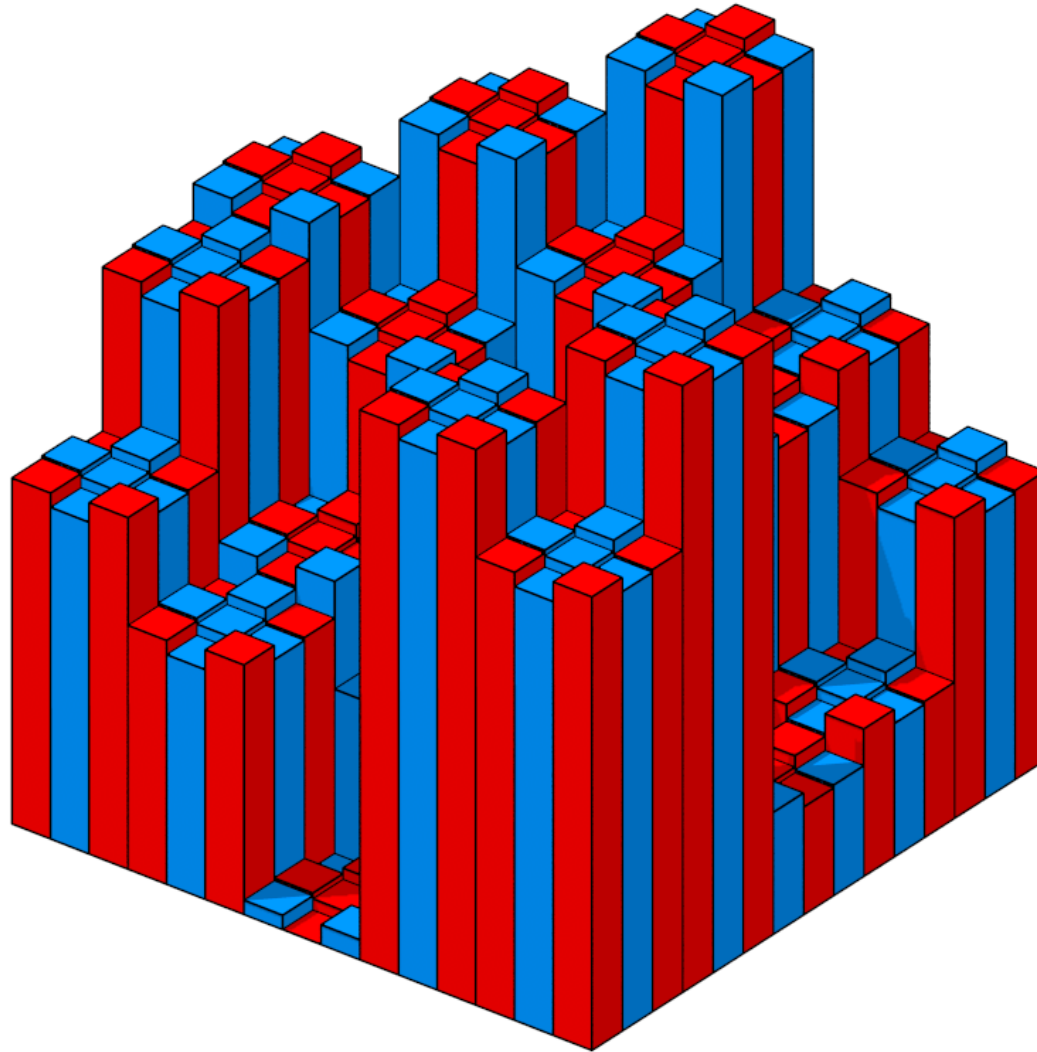
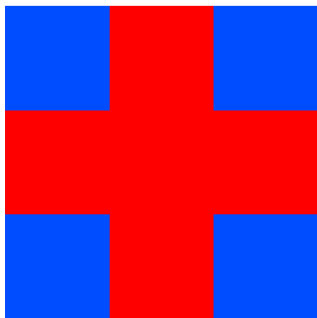
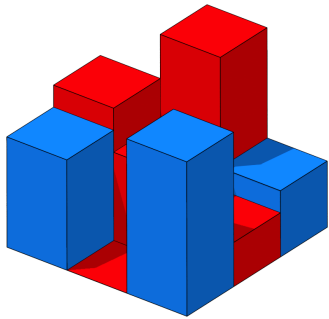


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17	23	4	5	11

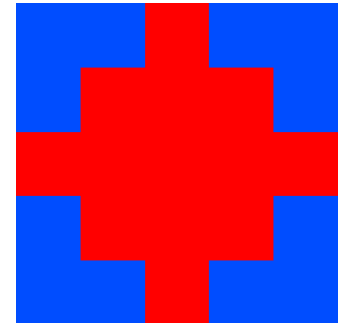
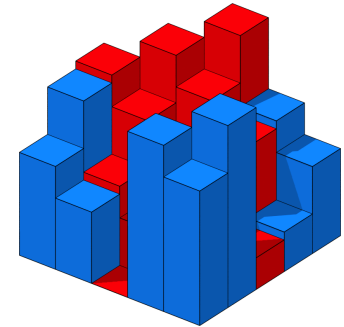


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0	4	8
7	2	3

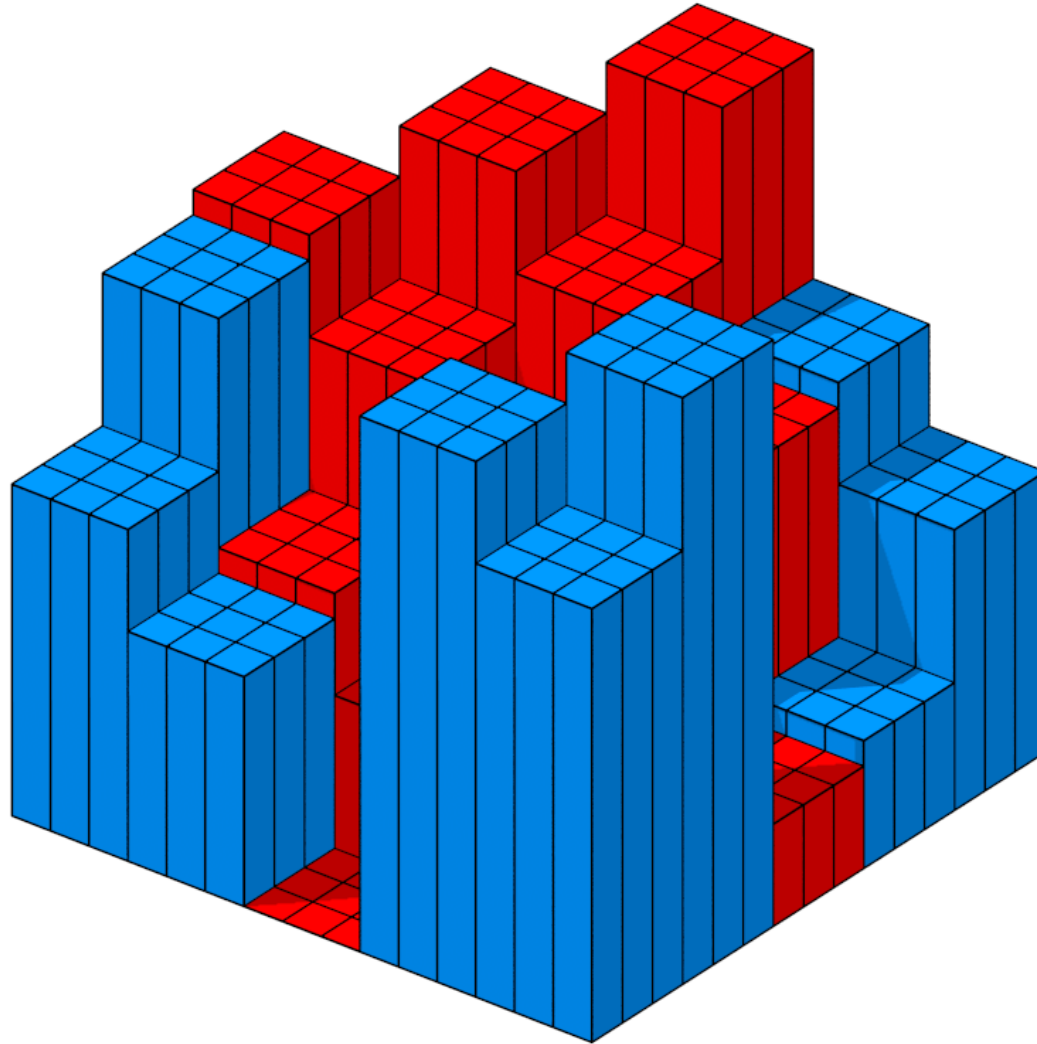
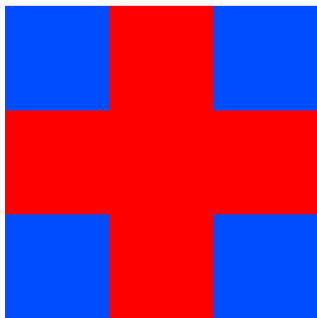
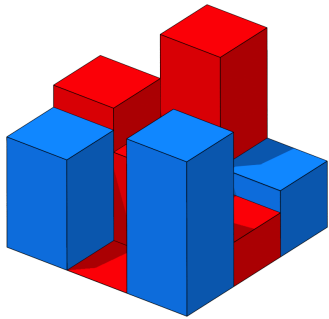


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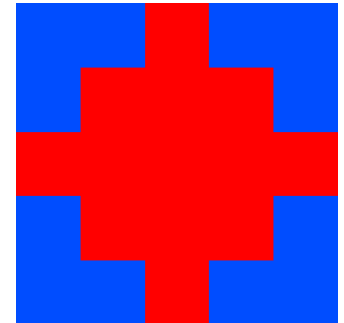
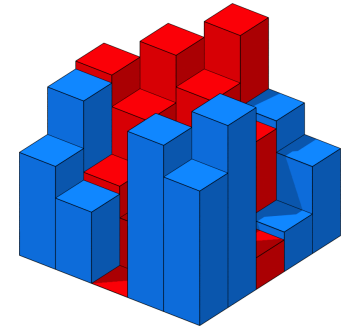


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0	4	8
7	2	3

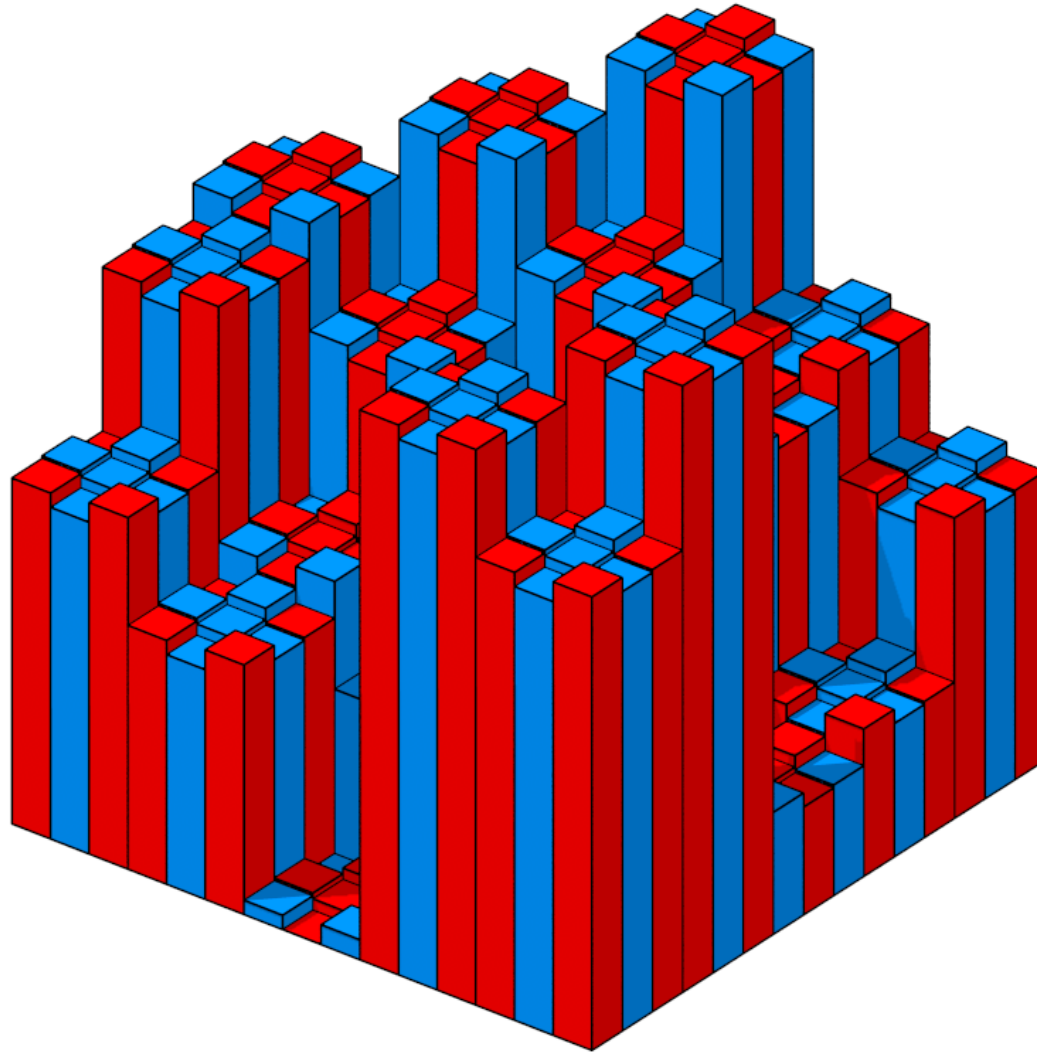
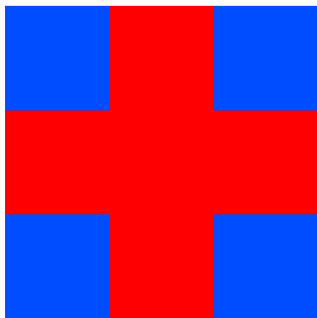
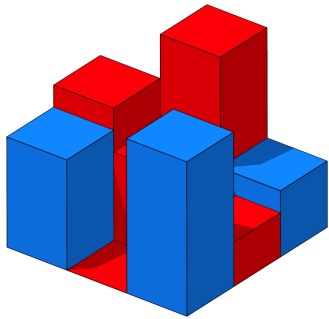


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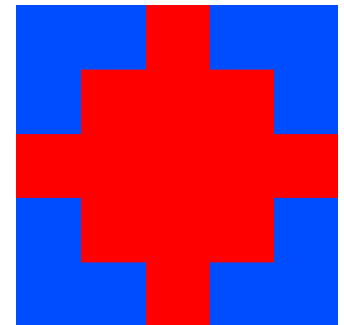
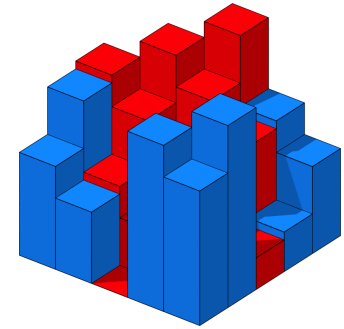


Verknüpfung

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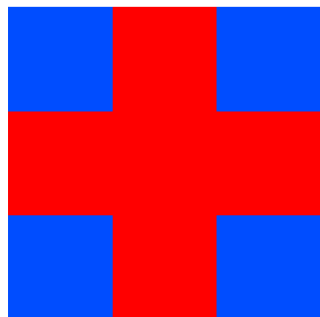
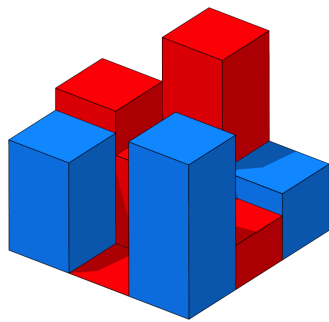


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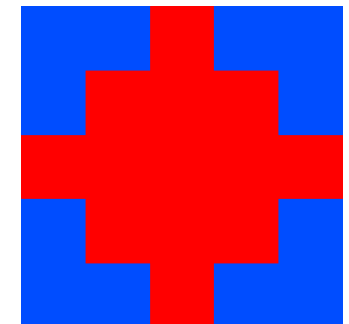
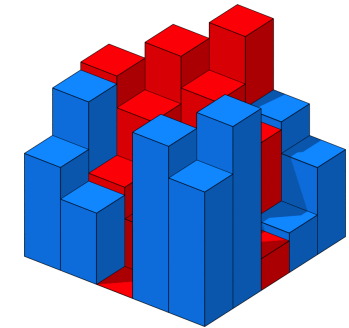
Verknüpfung

5	6	1
0	4	8
7	2	3



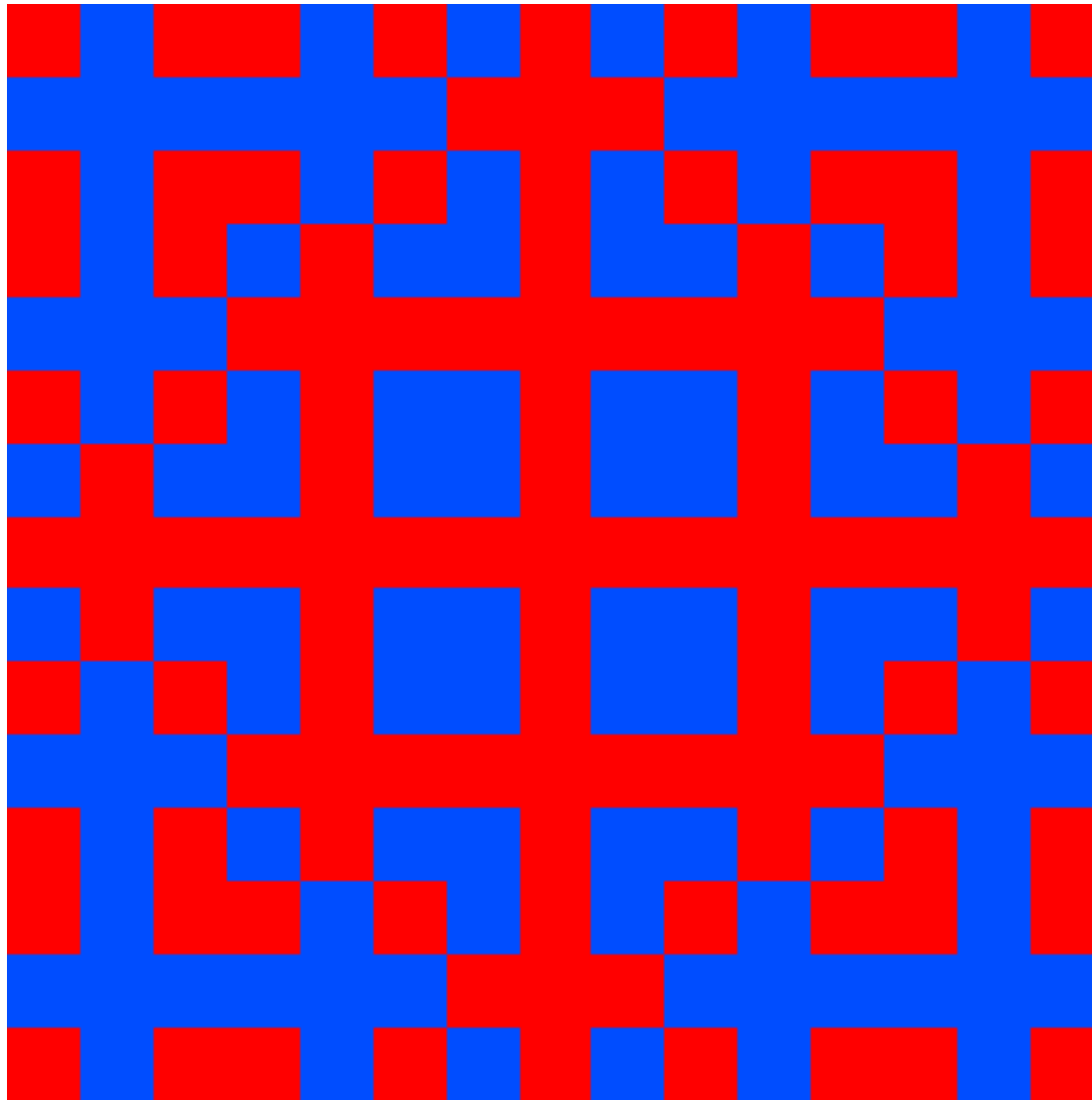
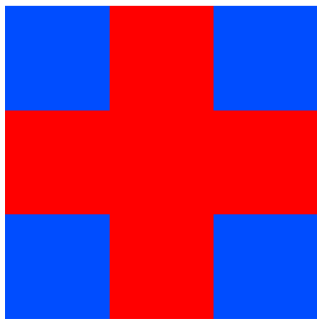
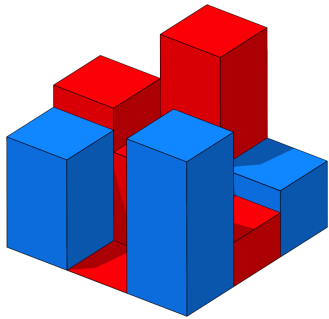
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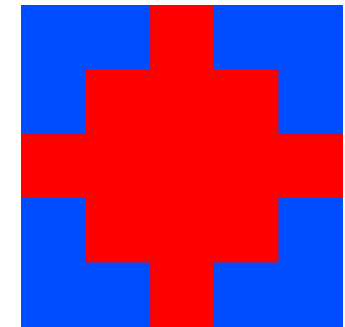
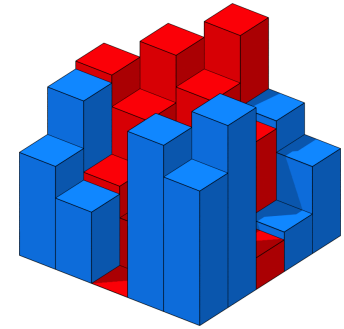


Verknüpfung

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0	4	8
7	2	3



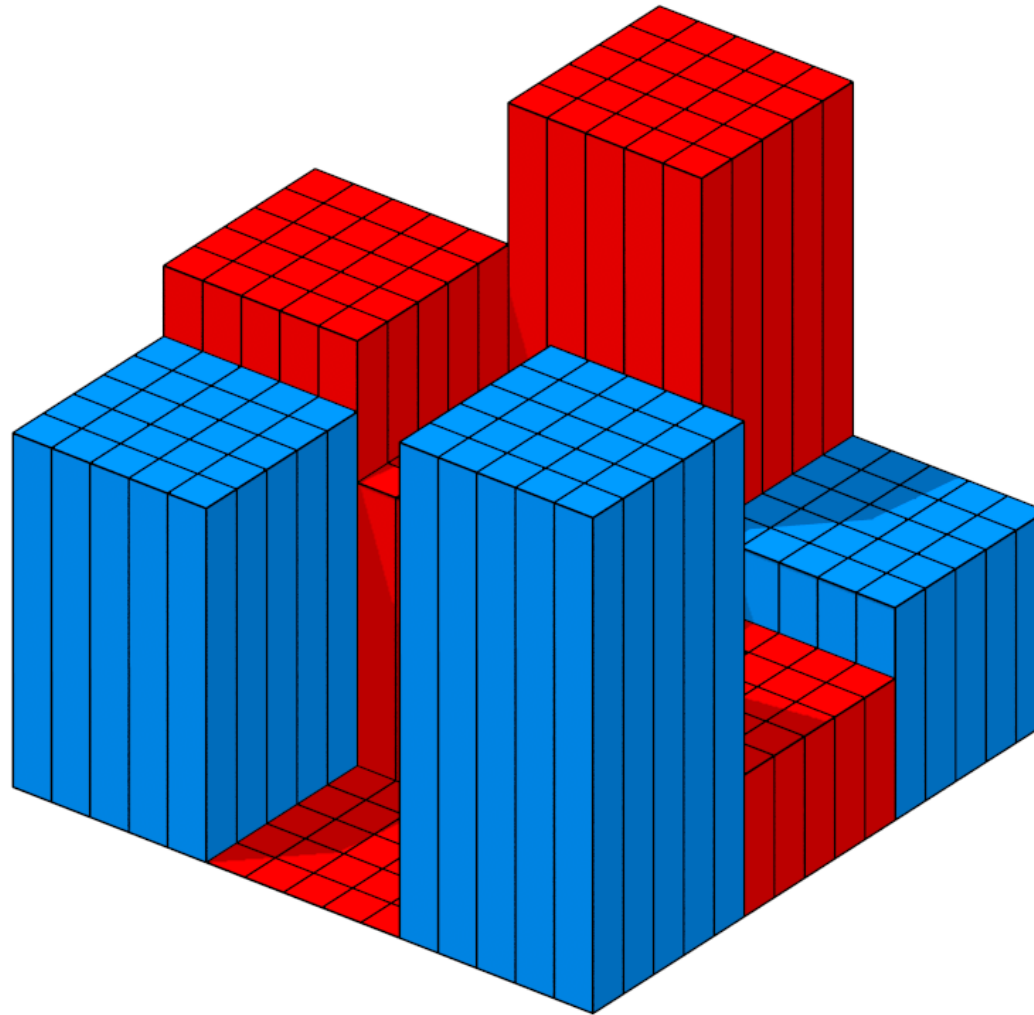
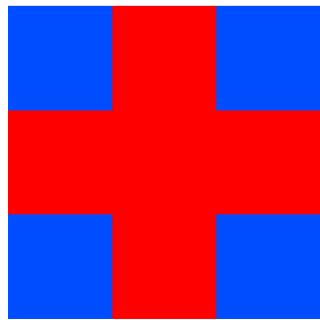
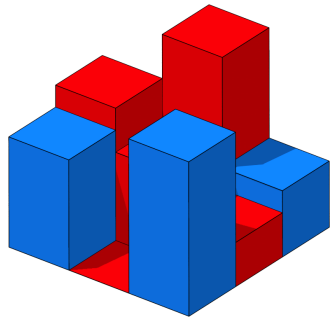
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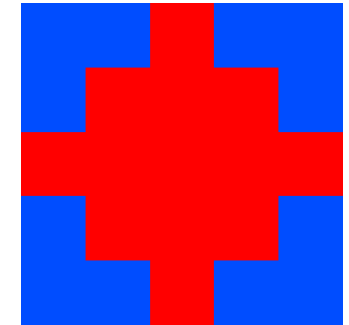
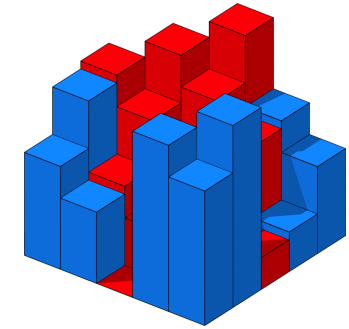
gerade / ungerade

Verknüpfung mit vertauschten Rollen

5	6	1
0	4	8
7	2	3

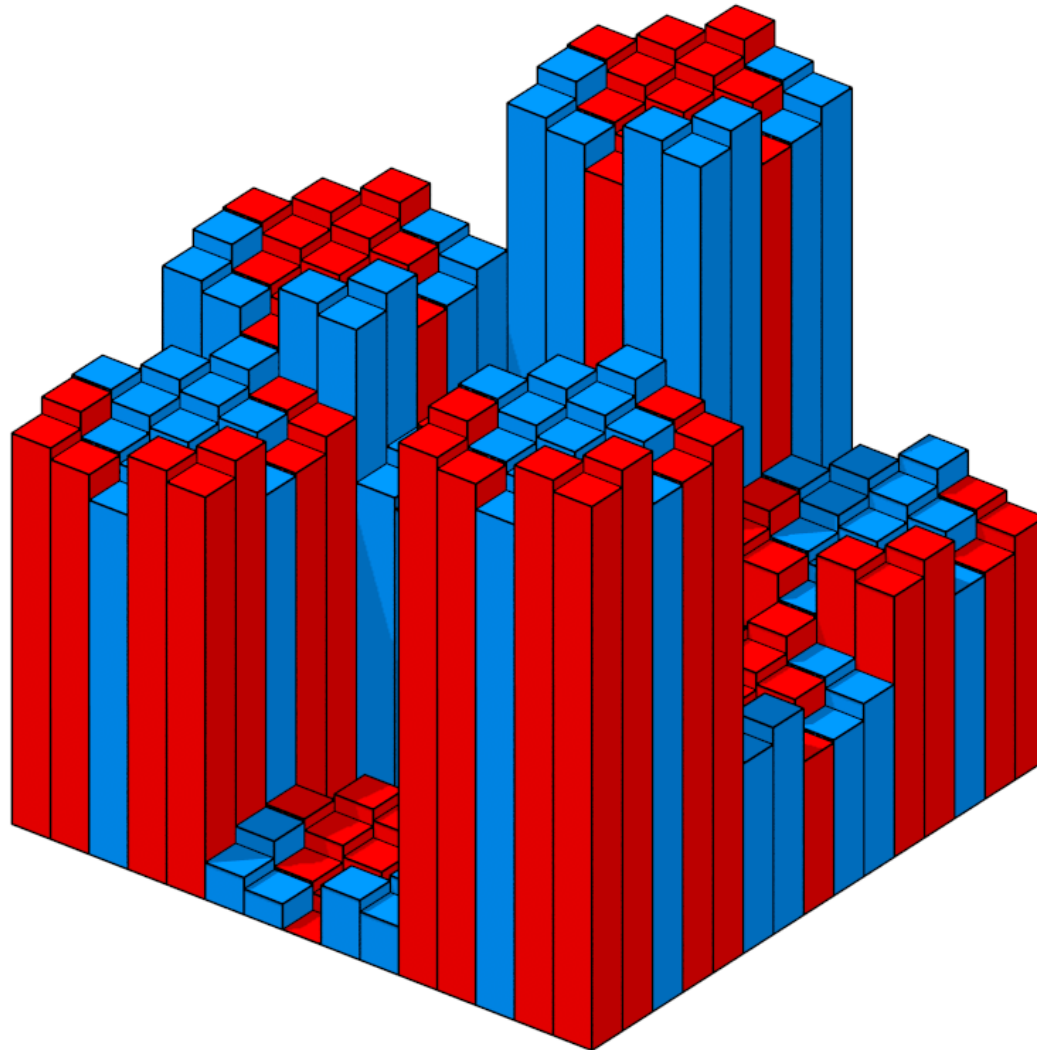
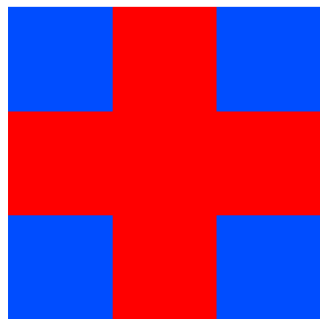
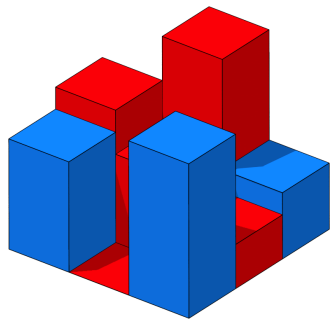


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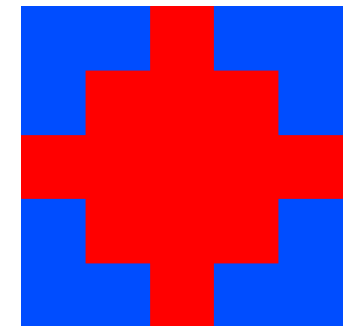
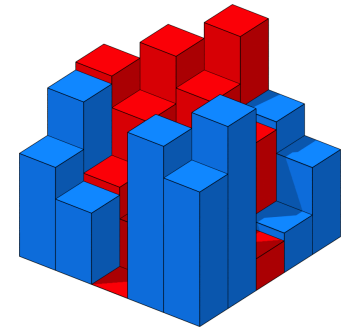


Verknüpfung mit vertauschten Rollen

5	6	1
0	4	8
7	2	3



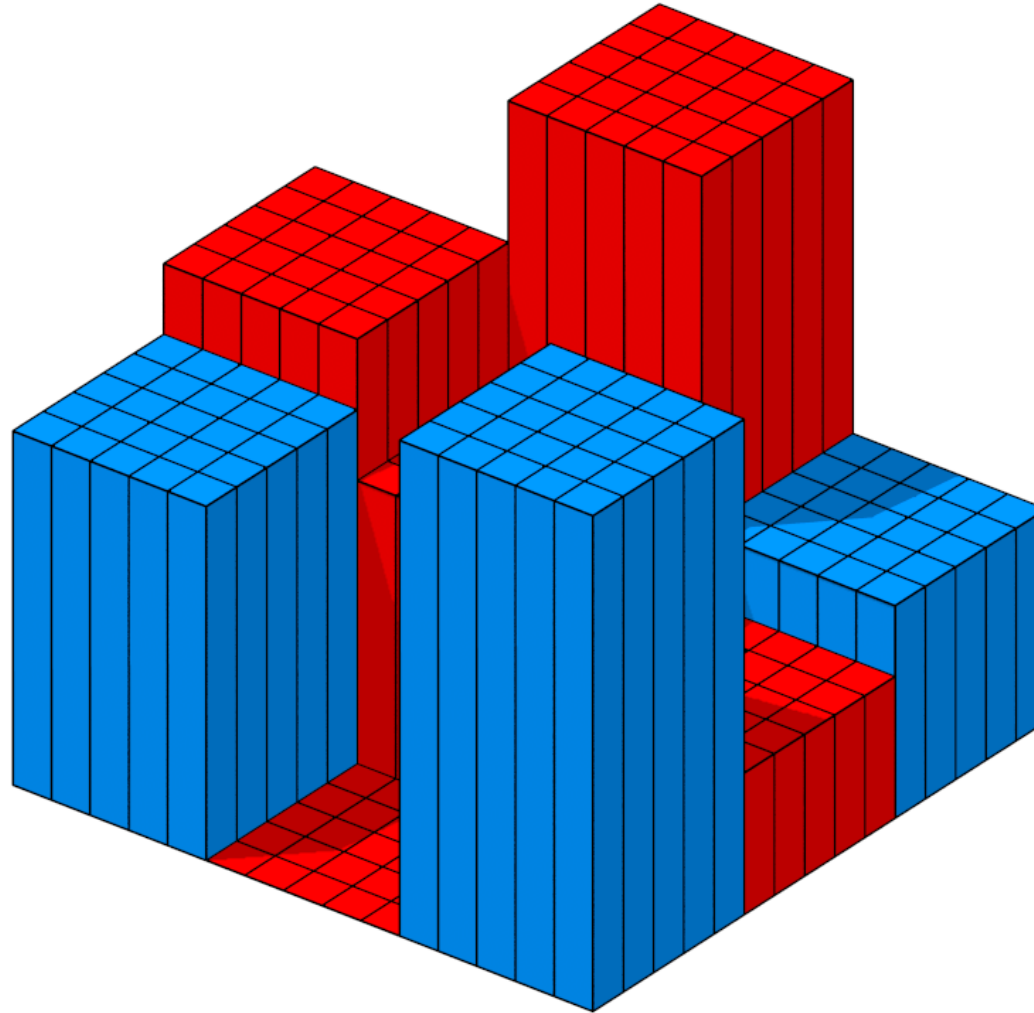
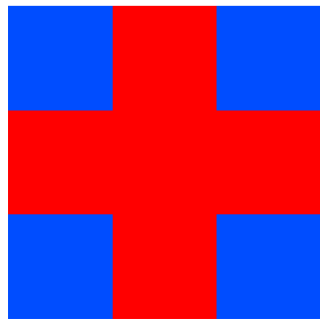
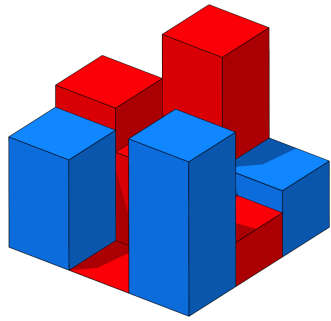
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17	23	4	5	11



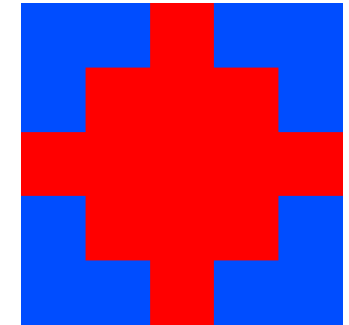
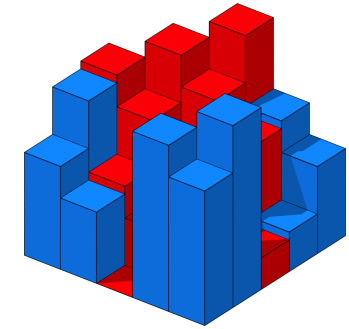
Nicht kommutativ

Verknüpfung mit vertauschten Rollen

5	6	1
0	4	8
7	2	3

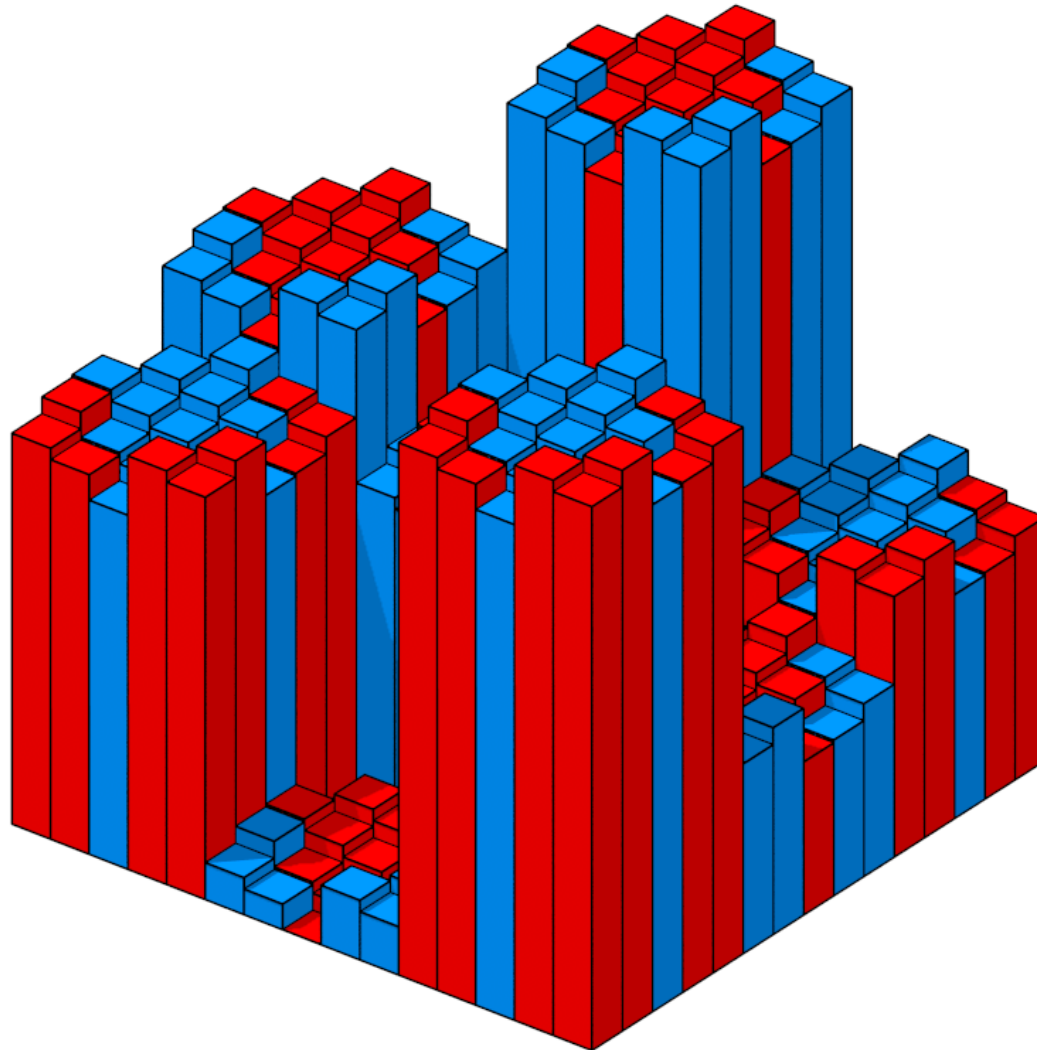
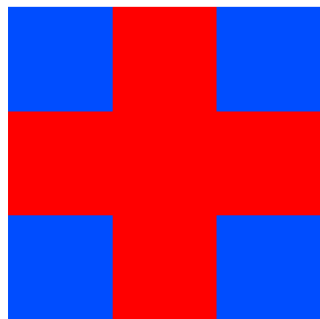
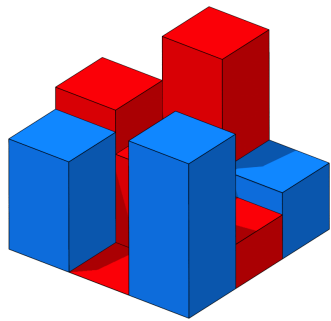


13	19	20	1	7
9	10	16	22	3
0	6	12	18	24
21	2	8	14	15
17	23	4	5	11

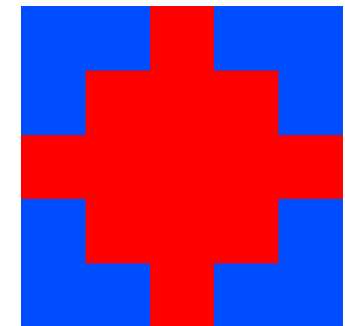
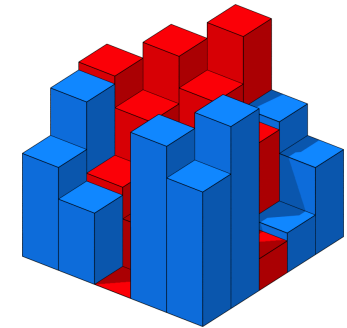


Verknüpfung mit vertauschten Rollen

5	6	1
0	4	8
7	2	3



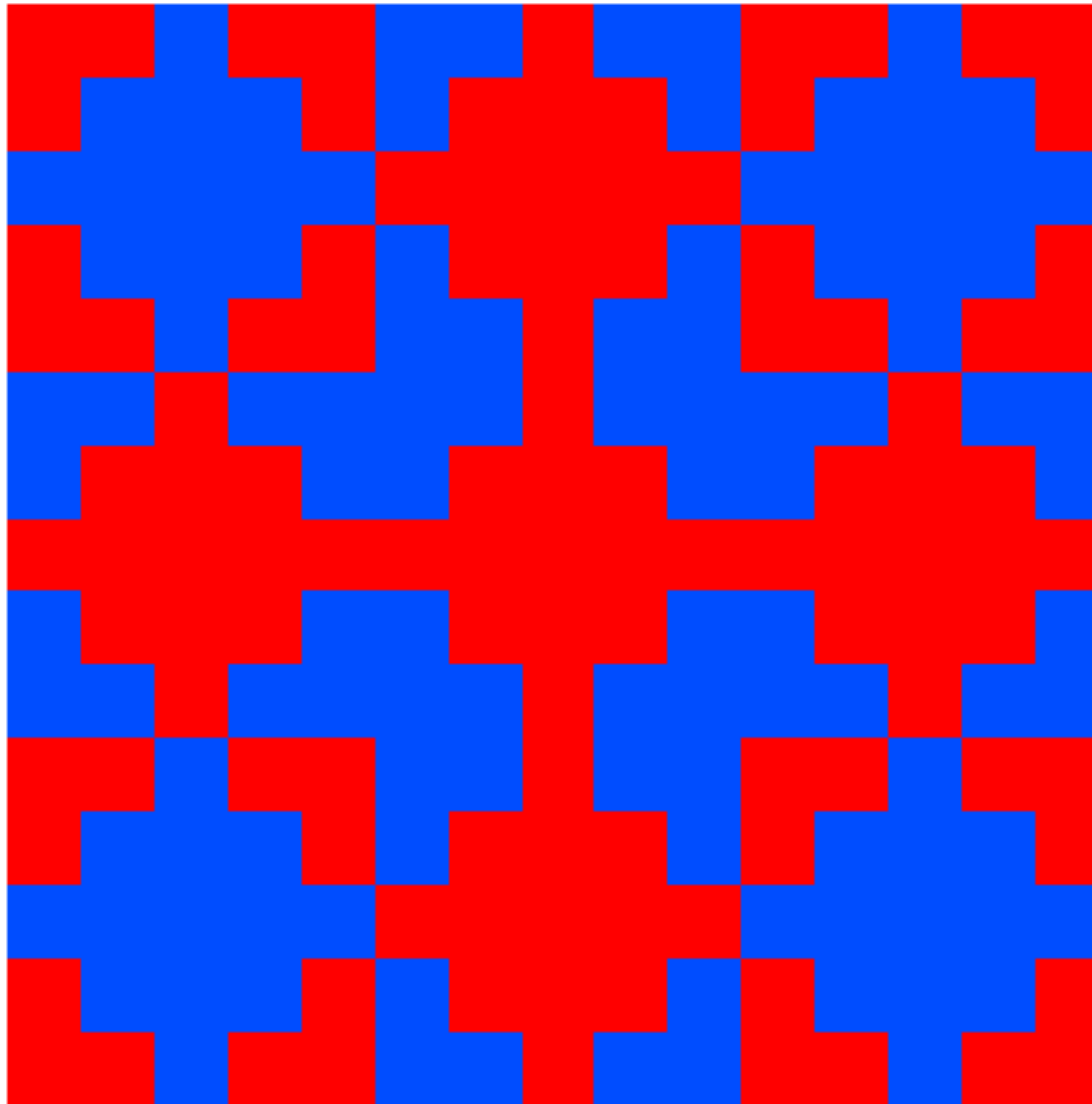
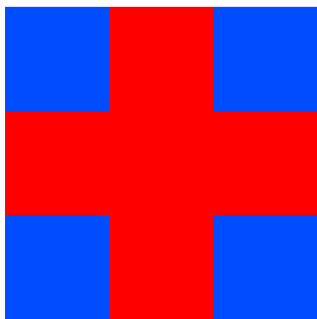
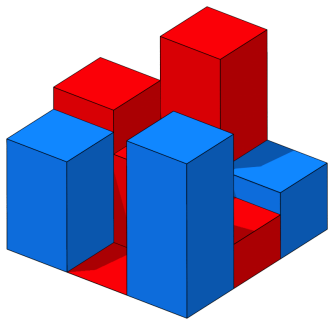
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9	10	16	22	3
0	6	12	18	24
21	2	8	14	15
17	23	4	5	11



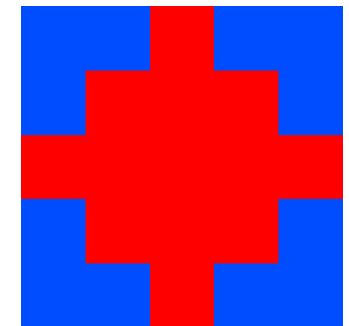
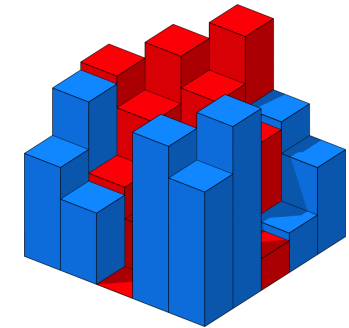
Nicht kommutativ

Verknüpfung mit vertauschten Rollen

5	6	1
0	4	8
7	2	3

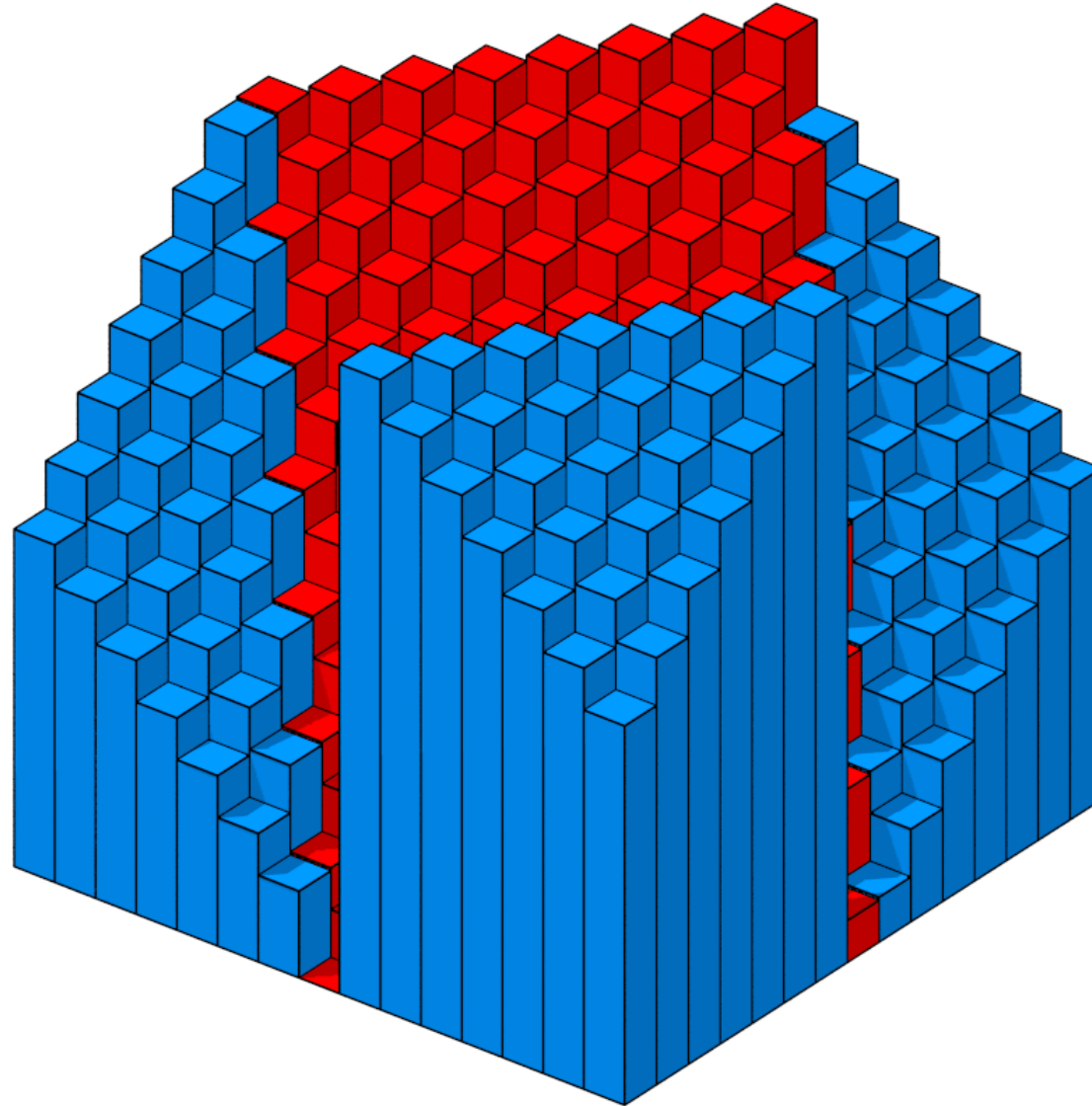


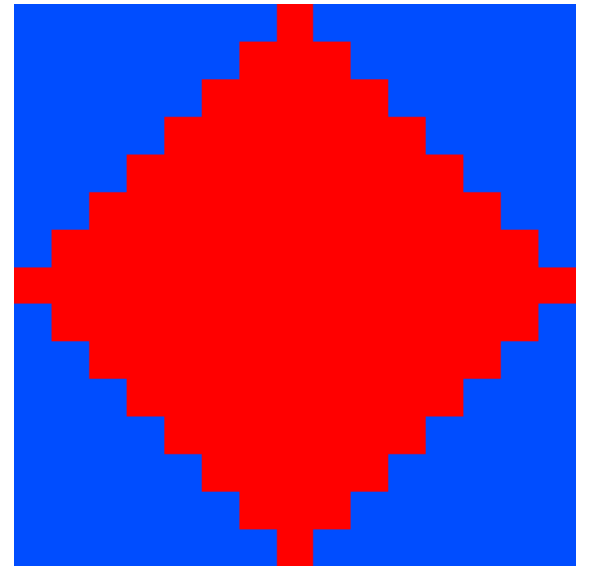
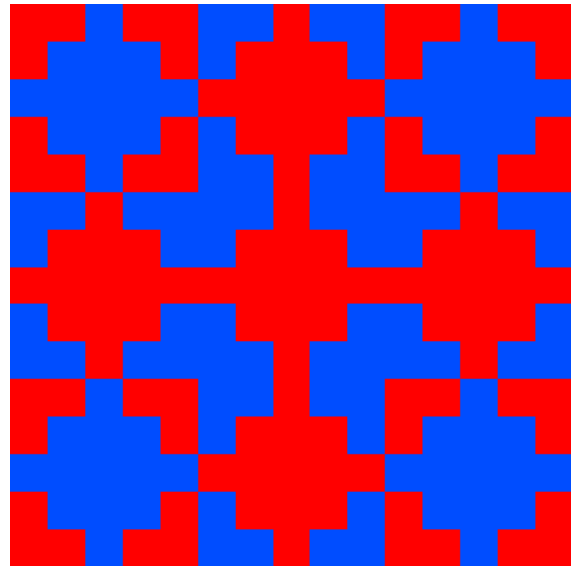
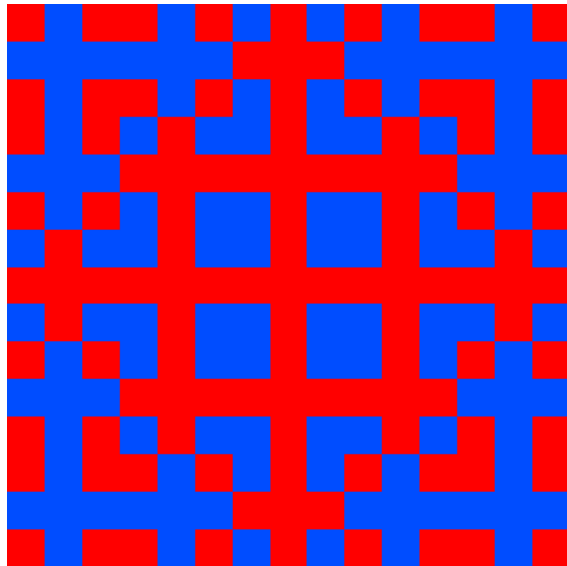
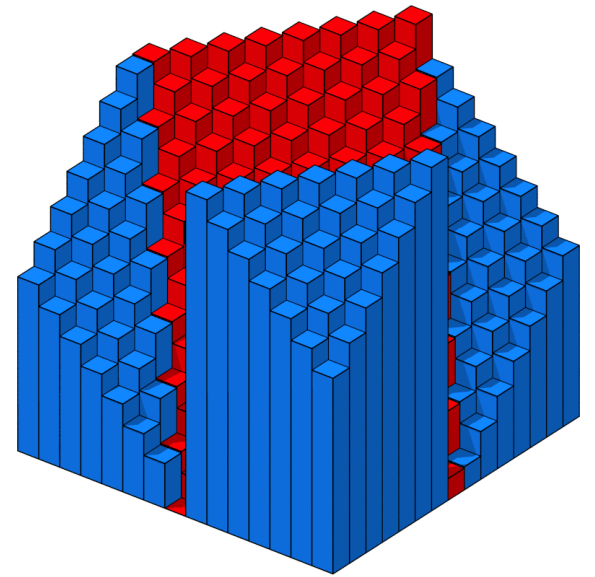
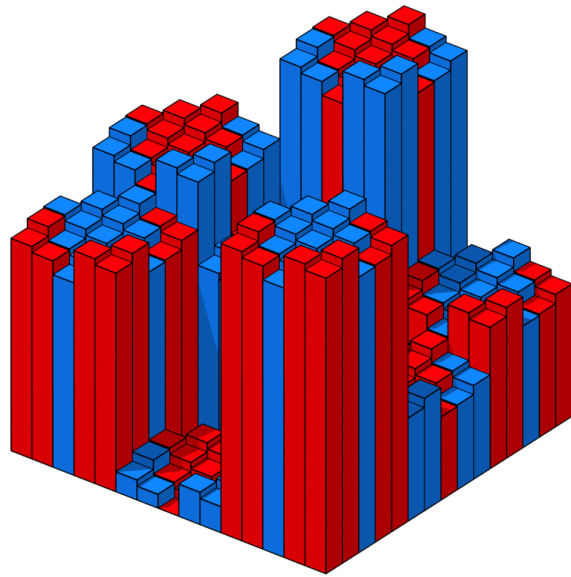
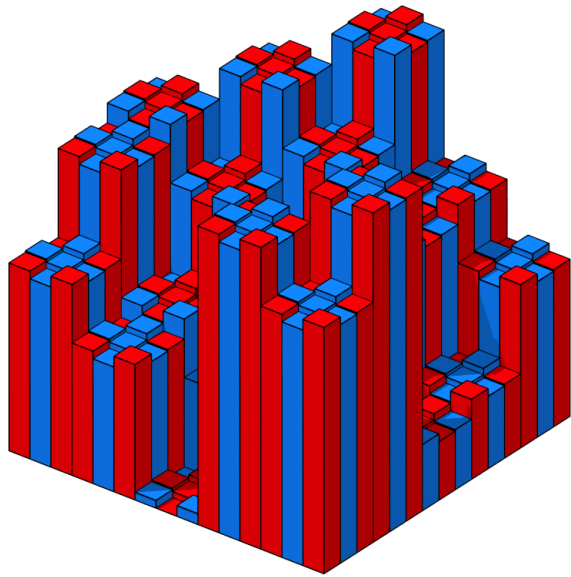
13	19	20	1	7
9	10	16	22	3
0	6	12	18	24
21	2	8	14	15
17	23	4	5	11



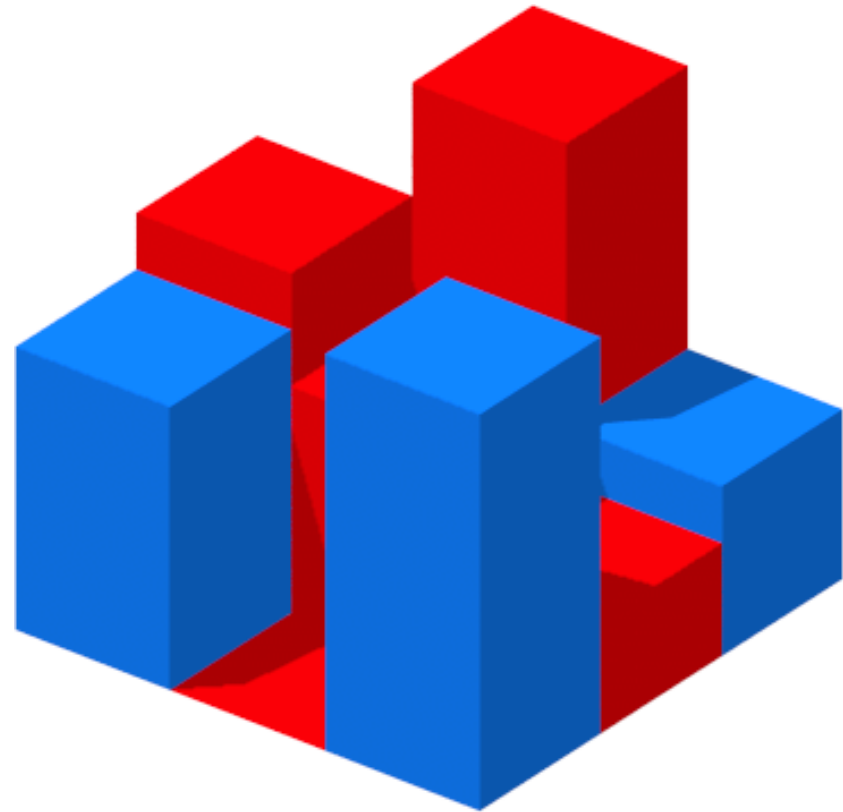
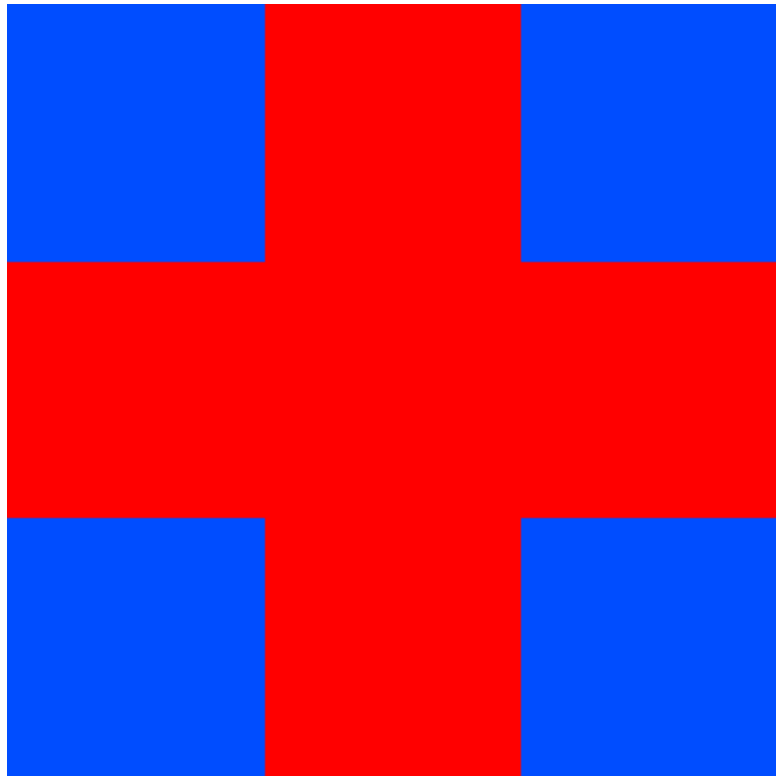
gerade / ungerade

Seitenlänge 15 direkt mit Formel

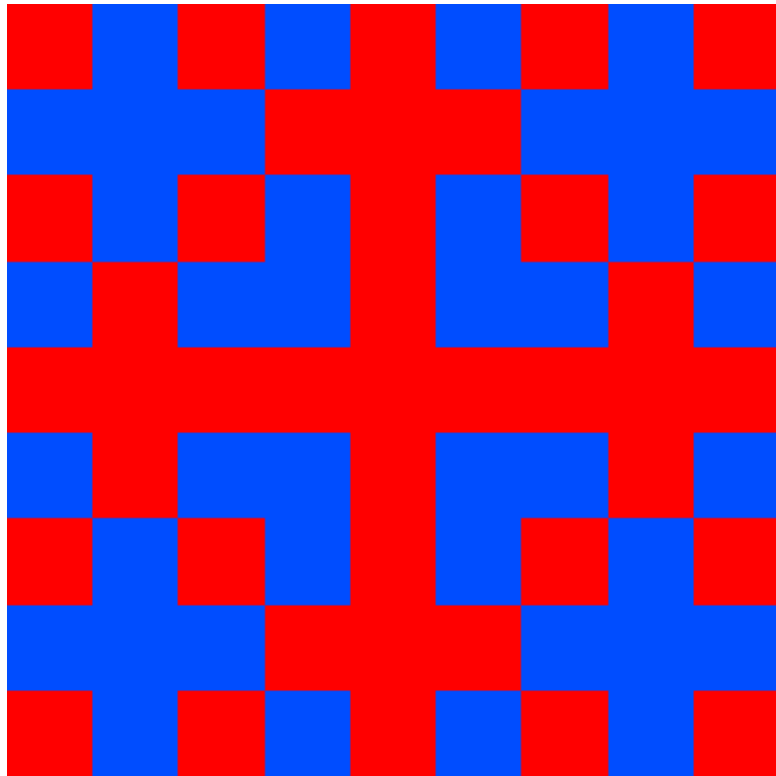




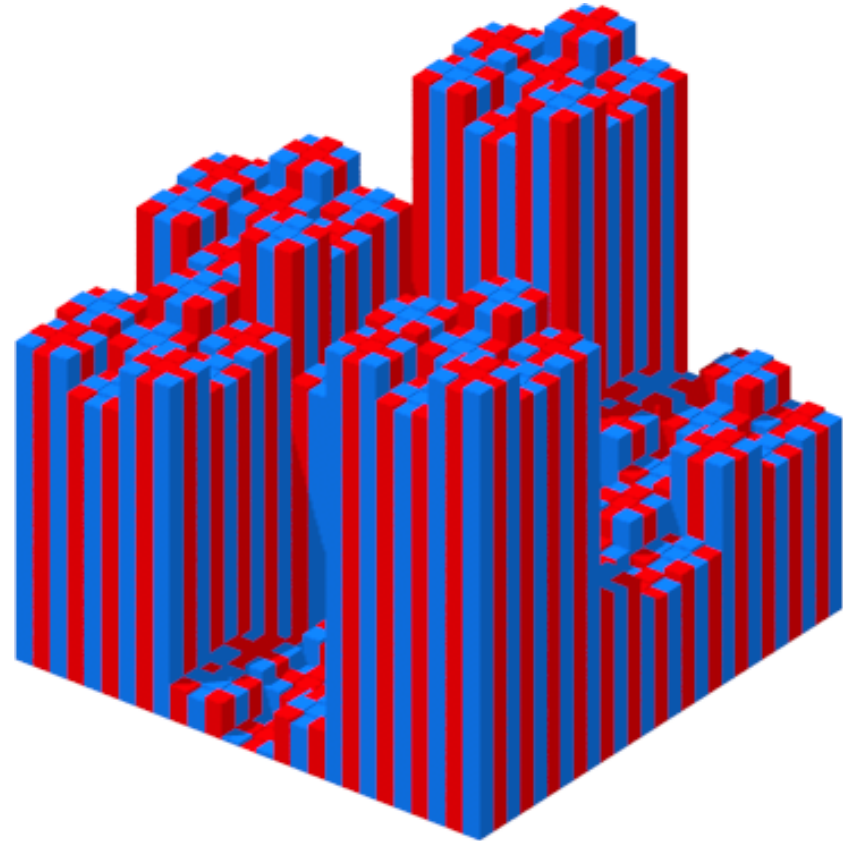
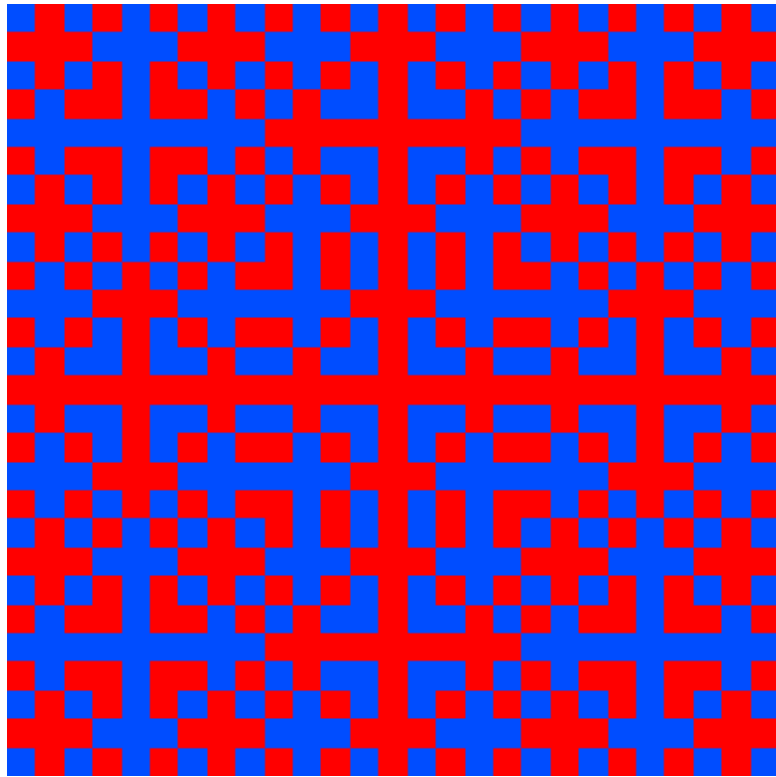
Potenzieren: $u = 3^1$ 9 Zahlen



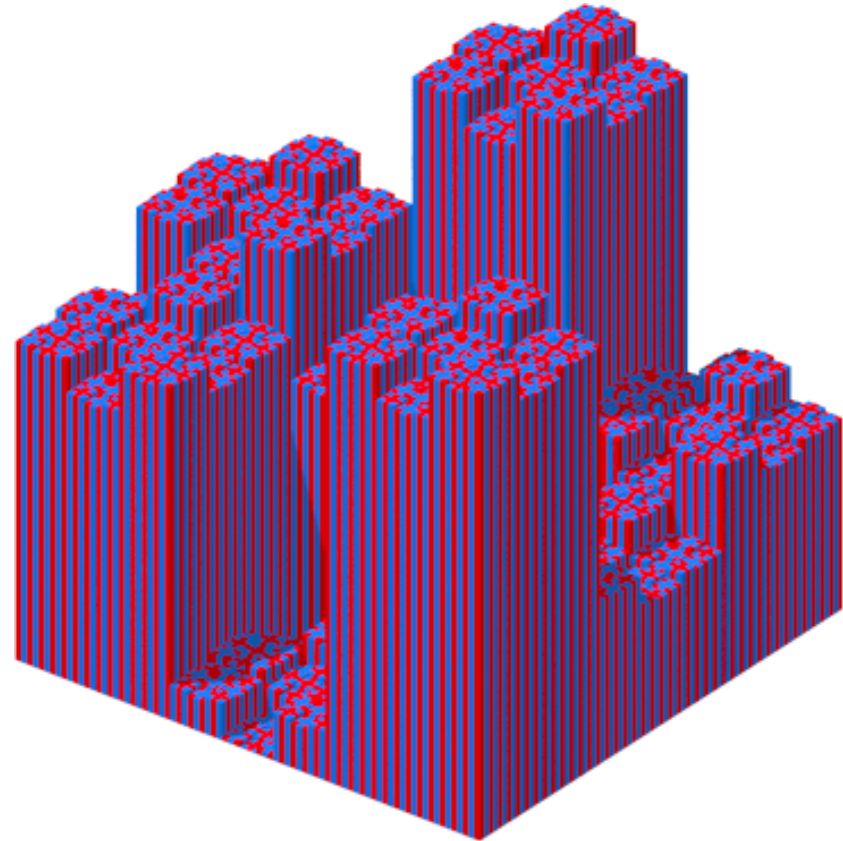
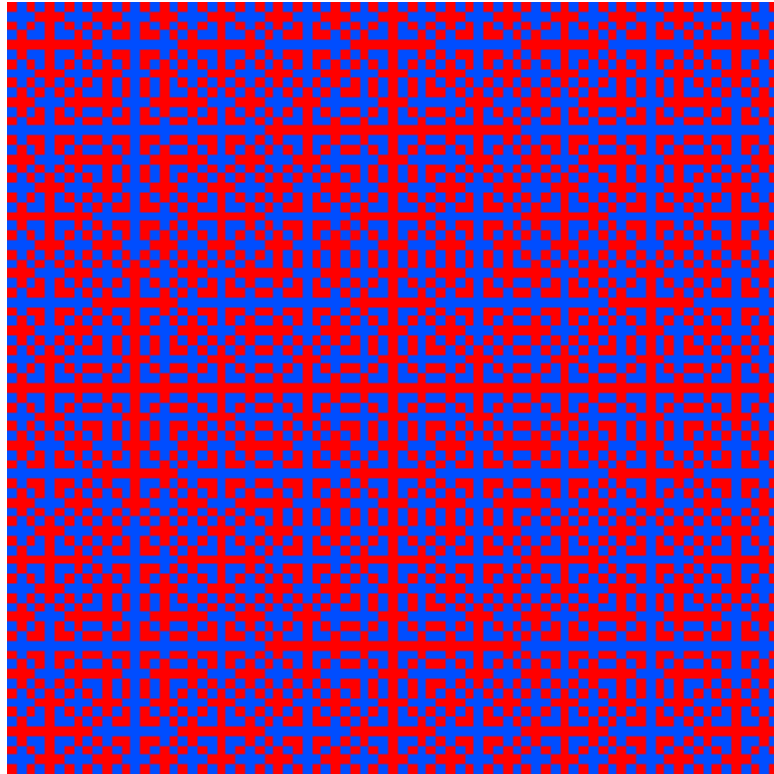
Potenzieren: $u = 3^2$ 81 Zahlen



Potenzieren: $u = 3^3$ 729 Zahlen



Potenzieren: $u = 3^4$ 6561 Zahlen





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