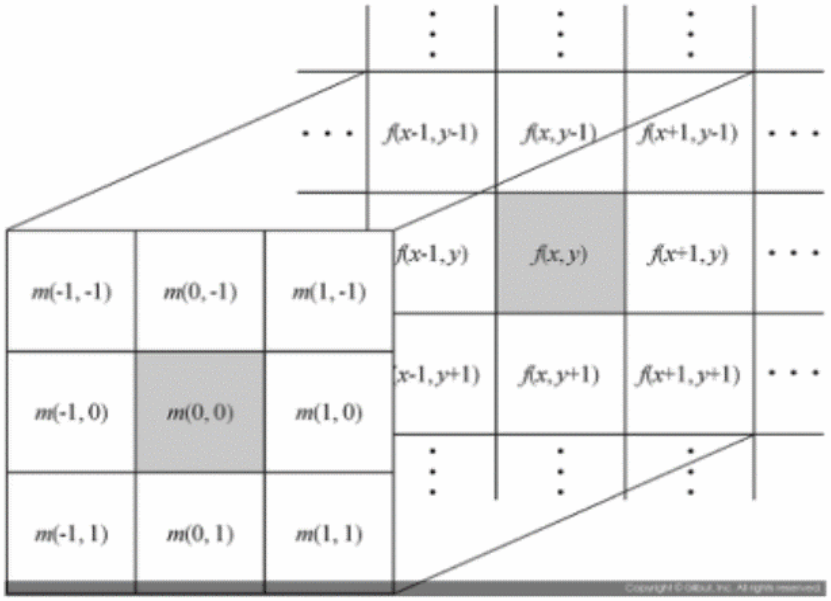
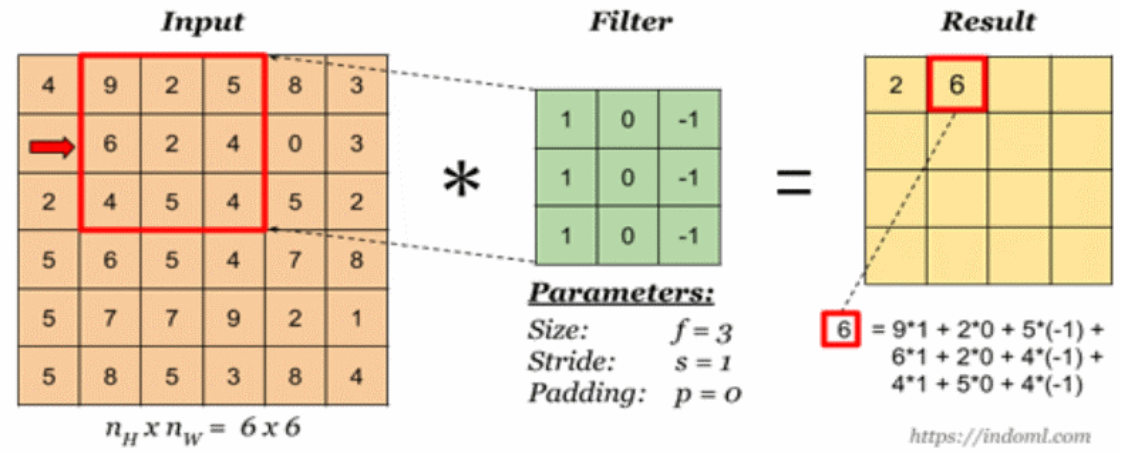
필터 컨볼루션

▼ 그림 8-1 마스크를 이용한 필터링 방법



마스크 연산에 의해 새로 결정되는 영상의 픽셀 값은 다음과 같다.

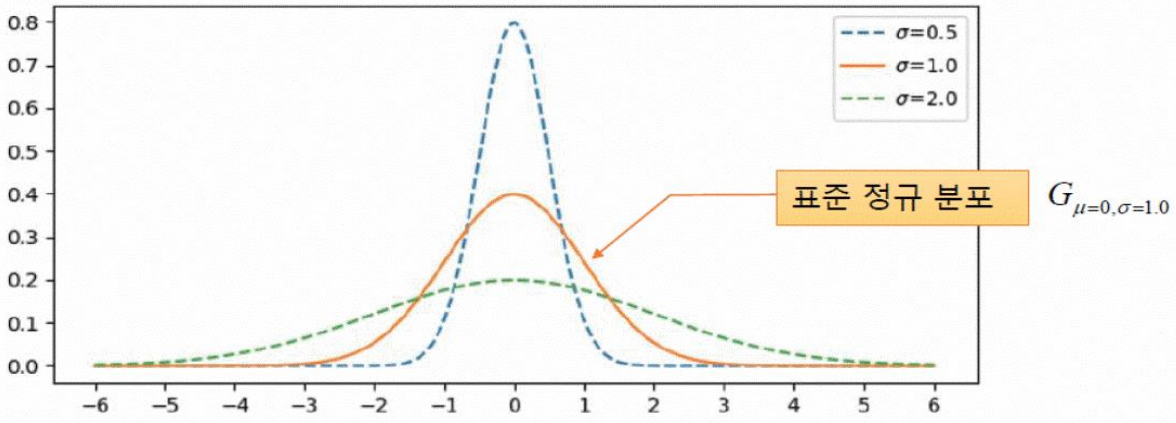
$$
\begin{aligned}
g(x,y) &= \sum_{j=-1}^{1}\sum_{i=-1}^{1} m(i,j) f(x+i,y+j) \\
&= m(-1,-1) f(x-1,y-1) + m(0,-1) f(x,y-1) + m(1,-1) f(x+1,y-1) \\
&\quad + m(-1,0) f(x-1,y) + m(0,0) f(x,y) + m(1,0) f(x+1,y) \\
&\quad + m(-1,1) f(x-1,y+1) + m(0,1) f(x,y+1) + m(1,1) f(x+1,y+1)
\end{aligned}
$$



가우시안 필터

$$G_{\mu,\sigma}(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

- μ : 평균
- σ : 표준편차



$$G_{\sigma}(x,y) = \frac{1}{2\pi\sigma^2} e^{\left(-\frac{x^2+y^2}{2\sigma^2}\right)}$$

$$\begin{cases} \mu_x = \mu_y = 0 \\ \sigma_x = \sigma_y = \sigma \end{cases}$$

2차원 가우시안 필터 마스크 (σ=1.0)

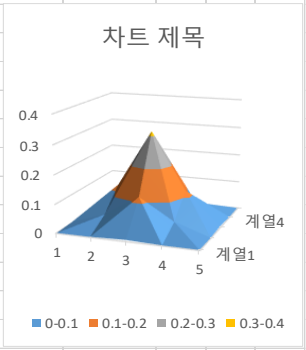
- 필터 마스크 크기 : (8σ + 1) 또는 (6σ + 1)

4	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0002	0.0011	0.0018	0.0011	0.0002	0.0000	0.0000
2	0.0000	0.0002	0.0029	0. 0131	0.0215	0.0131	0.0029	0.0002	0.0000
1	0.0000	0.0011	0.0131	0.0585	0.0965	0.0585	0.0131	0.0011	0.0000
0	0.0001	0.0018	0.0215	0.0965	0.1592	0.0965	0.0215	0.0018	0.0001
-1	0.0000	0.0011	0.0131	0.0585	0.0965	0.0585	0.0131	0.0011	0.0000
-2	0.0000	0.0002	0.0029	0. 0131	0.0215	0.0131	0.0029	0.0002	0.0000
-3	0.0000	0.0000	0.0002	0.0011	0.0018	0.0011	0.0002	0.0000	0.0000
-4	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
	-4	-3	-2	-1	0	1	2	3	4

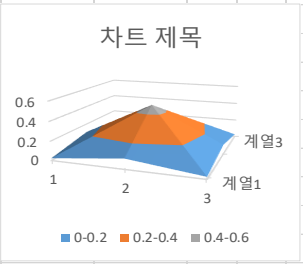
시그마	9x9										
1		-4	-3	-2	-1	0	1	2	3	4	
1	4	0	0	0	0	0.0001	0	0	0	0	0.0001
1	3	0	0	0.0002	0.0011	0.0018	0.0011	0.0002	0	0	0.0044
1	2	0	0.0002	0.0029	0.0131	0.0215	0.0131	0.0029	0.0002	0	0.0539
1	1	0	0.0011	0.0131	0.0585	0.0965	0.0585	0.0131	0.0011	0	0.2419
1	0	0.0001	0.0018	0.0215	0.0965	0.1592	0.0965	0.0215	0.0018	0.0001	0.399
1	-1	0	0.0011	0.0131	0.0585	0.0965	0.0585	0.0131	0.0011	0	0.2419
1	-2	0	0.0002	0.0029	0.0131	0.0215	0.0131	0.0029	0.0002	0	0.0539
1	-3	0	0	0.0002	0.0011	0.0018	0.0011	0.0002	0	0	0.0044
1	-4	0	0	0	0	0.0001	0	0	0	0	0.0001
											0.9996

시그마	7x7										
0.92		-4	-3	-2	-1	0	1	2	3	4	
0.92	4										0
0.92	3		0	0.0001	0.0005	0.0009	0.0005	0.0001	0		0.0021
0.92	2		0.0001	0.0017	0.0098	0.0177	0.0098	0.0017	0.0001		0.0409
0.92	1		0.0005	0.0098	0.0577	0.1042	0.0577	0.0098	0.0005		0.2402
0.92	0		0.0009	0.0177	0.1042	0.188	0.1042	0.0177	0.0009		0.4336
0.92	-1		0.0005	0.0098	0.0577	0.1042	0.0577	0.0098	0.0005		0.2402
0.92	-2		0.0001	0.0017	0.0098	0.0177	0.0098	0.0017	0.0001		0.0409
0.92	-3		0	0.0001	0.0005	0.0009	0.0005	0.0001	0		0.0021
0.92	-4										0
											1

시그마	5x5										
0.71		-4	-3	-2	-1	0	1	2	3	4	
0.71	4										0
0.71	3										0
0.71	2			0.0001	0.0022	0.006	0.0022	0.0001			0.0106
0.71	1			0.0022	0.0434	0.1171	0.0434	0.0022			0.2083
0.71	0			0.006	0.1171	0.3157	0.1171	0.006			0.5619
0.71	-1			0.0022	0.0434	0.1171	0.0434	0.0022			0.2083
0.71	-2			0.0001	0.0022	0.006	0.0022	0.0001			0.0106
0.71	-3										0
0.71	-4										0
											0.9997



시그마	3x3										
0.58		-4	-3	-2	-1	0	1	2	3	4	
0.58	4										0
0.58	3										0
0.58	2										0
0.58	1				0.0242	0.107	0.0242				0.1554
0.58	0				0.107	0.4731	0.107				0.6871
0.58	-1				0.0242	0.107	0.0242				0.1554
0.58	-2										0
0.58	-3										0
0.58	-4										0
											0.9979



라플라시안 필터

$$\nabla^2 f = \frac{d^2 f}{dx^2} + \frac{d^2 f}{dy^2}$$

$$\frac{d^2 f}{dx^2} = \frac{df(x+1,y)}{dx} - \frac{df(x,y)}{dx}$$

$$= [f(x+1,y) - f(x,y)] - [f(x,y) - f(x-1,y)]$$

$$= f(x+1,y) - 2f(x,y) + f(x-1,y)$$

$$\frac{d^2 f}{dy^2} = \frac{df(x,y+1)}{dy} - \frac{df(x,y)}{dy}$$

$$= [f(x,y+1) - f(x,y)] - [f(x,y) - f(x,y-1)]$$

$$= f(x,y+1) - 2f(x,y) + f(x,y-1)$$

$$\nabla^2 f(x,y) = f(x-1,y) + f(x+1,y) + f(x,y-1) + f(x,y+1) - 4f(x,y)$$

1	1	1
1	-8	1
1	1	1

(a) 3x3 라플라시안 마스크
(OFF-center 신경절세포 모방)

0	0	1	0	0
0	1	2	1	0
1	2	-16	2	1
0	1	2	1	0
0	0	1	0	0

(b) 5x5 라플라시안 마스크
(OFF-center 신경절세포 모방)

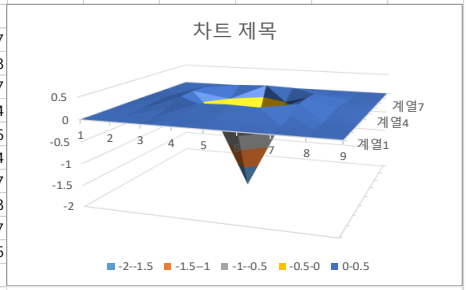
-1	-1	-1
-1	8	-1
-1	-1	-1

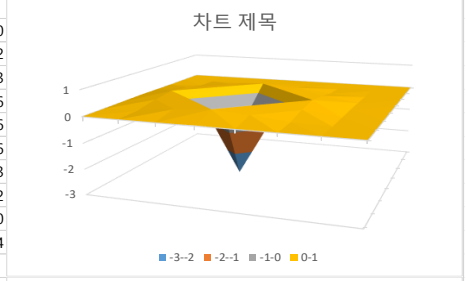
(c) 3x3 라플라시안 마스크
(ON-center 신경절세포 모방)

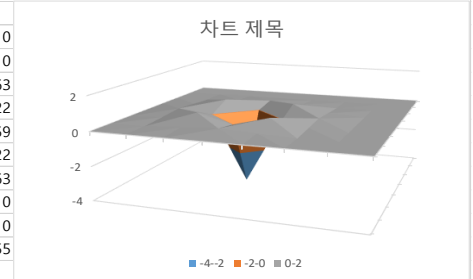
0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

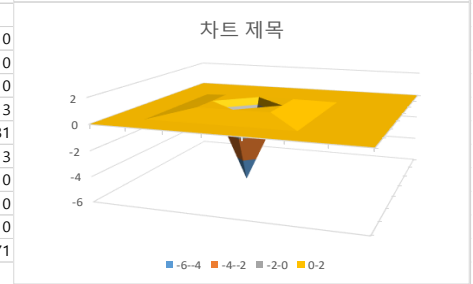
(d) 5x5 라플라시안 마스크
(ON-center 신경절세포 모방)

9	9x9											
1		-4	-3	-2	-1	0	1	2	3	4		
1	4	0	0.0001	0.0008	0.0031	0.0047	0.0031	0.0008	0.0001	0	0.0127	
1	3	0.0001	0.002	0.0165	0.0539	0.0778	0.0539	0.0165	0.002	0.0001	0.2228	
1	2	0.0008	0.0165	0.1099	0.2463	0.2707	0.2463	0.1099	0.0165	0.0008	1.0177	
1	1	0.0031	0.0539	0.2463	0	-0.6065	0	0.2463	0.0539	0.0031	1E-04	
1	0	0.0047	0.0778	0.2707	-0.607	-2	-0.607	0.2707	0.0778	0.0047	-2.5066	
1	-1	0.0031	0.0539	0.2463	0	-0.6065	0	0.2463	0.0539	0.0031	1E-04	
1	-2	0.0008	0.0165	0.1099	0.2463	0.2707	0.2463	0.1099	0.0165	0.0008	1.0177	
1	-3	0.0001	0.002	0.0165	0.0539	0.0778	0.0539	0.0165	0.002	0.0001	0.2228	
1	-4	0	0.0001	0.0008	0.0031	0.0047	0.0031	0.0008	0.0001	0	0.0127	
											-4.9E-16	
7	7x7											
0.83		-4	-3	-2	-1	0	1	2	3	4		
0.83	4										0	
0.83	3		0.0001	0.002	0.0128	0.0234	0.0128	0.002	0.0001		0.0532	
0.83	2		0.002	0.042	0.2026	0.3031	0.2026	0.042	0.002		0.7963	
0.83	1		0.0128	0.2026	0.307	-0.3852	0.307	0.2026	0.0128		0.6596	
0.83	0		0.0234	0.3031	-0.385	-2.9032	-0.385	0.3031	0.0234		-3.0206	
0.83	-1		0.0128	0.2026	0.307	-0.3852	0.307	0.2026	0.0128		0.6596	
0.83	-2		0.002	0.042	0.2026	0.3031	0.2026	0.042	0.002		0.7963	
0.83	-3		0.0001	0.002	0.0128	0.0234	0.0128	0.002	0.0001		0.0532	
0.83	-4										0	
											-0.0024	
5	5x5											
0.71		-4	-3	-2	-1	0	1	2	3	4		
0.71	4										0	
0.71	3										0	
0.71	2			0.0099	0.1102	0.2228	0.1102	0.0099			0.463	
0.71	1			0.1102	0.5369	-0.012	0.5369	0.1102			1.2822	
0.71	0			0.2228	-0.012	-3.9675	-0.012	0.2228			-3.5459	
0.71	-1			0.1102	0.5369	-0.012	0.5369	0.1102			1.2822	
0.71	-2			0.0099	0.1102	0.2228	0.1102	0.0099			0.463	
0.71	-3										0	
0.71	-4										0	
											-0.0555	
3	3x3											
0.59		-4	-3	-2	-1	0	1	2	3	4		
0.59	4										0	
0.59	3										0	
0.59	2										0	
0.59	1				0.6084	0.5962	0.6084				1.813	
0.59	0				0.5962	-5.7455	0.5962				-4.5531	
0.59	-1				0.6084	0.5962	0.6084				1.813	
0.59	-2										0	
0.59	-3										0	
0.59	-4										0	
											-0.9271	



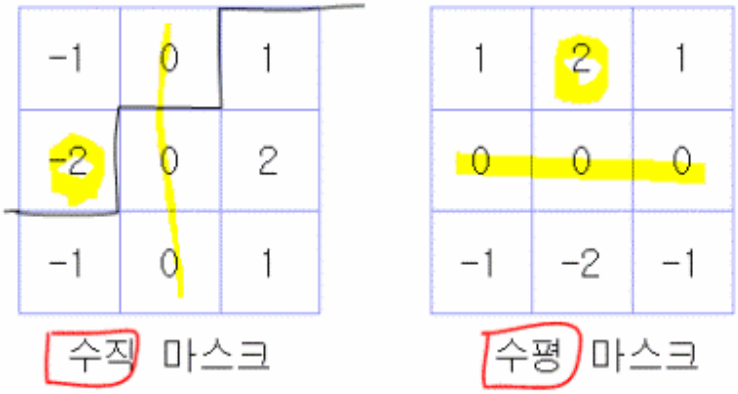






소벨 필터

3. 소벨(Sobel) 에지추출
   1) 에지 추출의 가장 대표적인 1차 미분 연산자중 하나
   2) 소벨 마스크 모양



   3) 소벨 마스크의 특징
      - 모든 방향의 에지 추출
      - 돌출한 화소값을 비교적 평균화하므로 잡음에 대체적으로 강함
      - 수직 수평 방향 에지 보다 대각선 방향 에지에 더 민감하게 반응
   4) 소벨 마스크의 크기 3x3으로 고정된 것은 아니다.
   5) 5x5 소벨 마스크

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

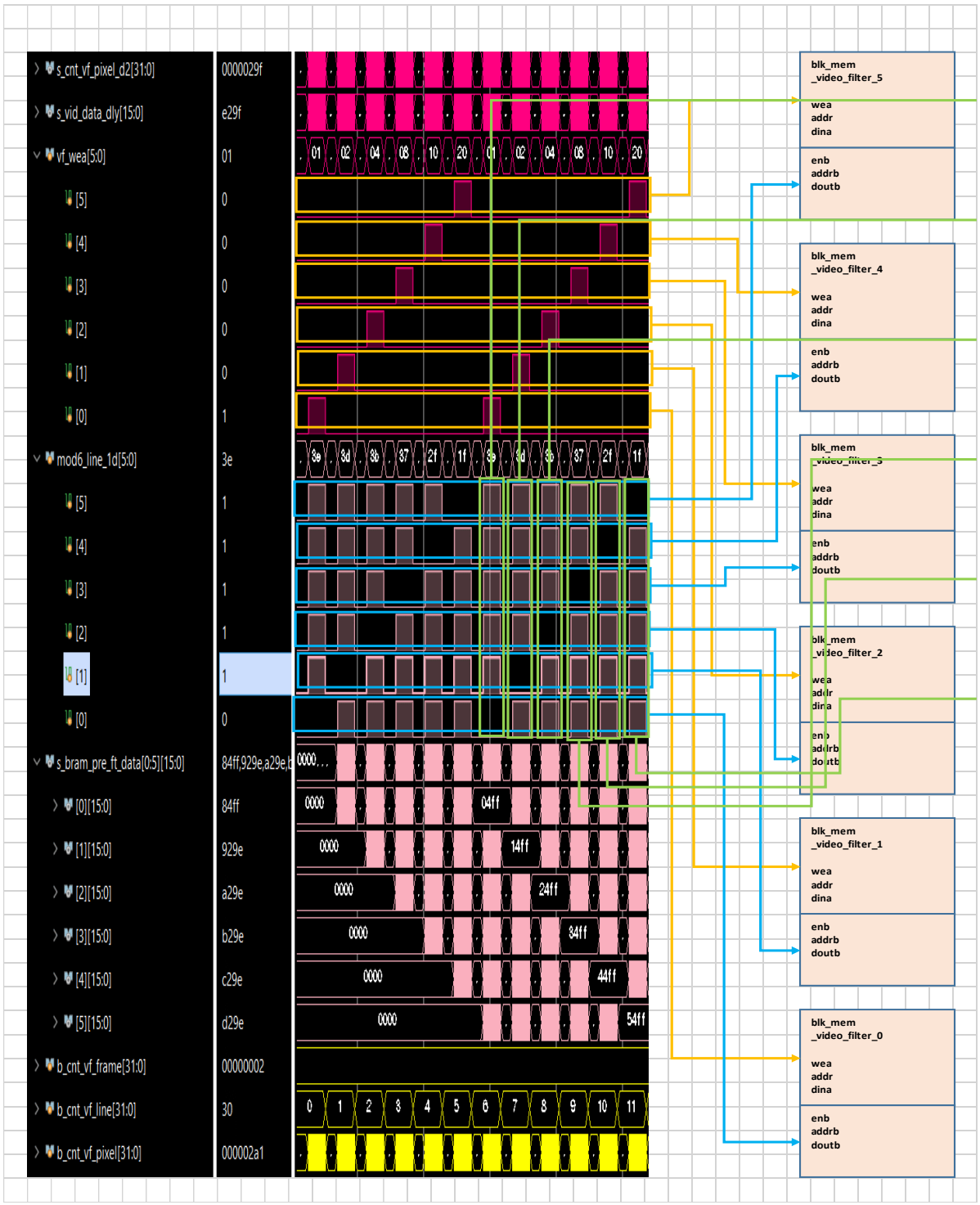
수직 마스크

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

수평 마스크

   6) **결과** : 3x3마스크보다에지가 더 두껍고 좋은 효과를 나타내지 못함

filter circular data align



```
else if( mod6_line_wt_wide[0]==1 )begin
    arrange_pre_ft_data          [0]      <= s_bram_pre_ft_data[1];
    arrange_pre_ft_data          [1]      <= s_bram_pre_ft_data[2];
    arrange_pre_ft_data          [2]      <= s_bram_pre_ft_data[3];
    arrange_pre_ft_data          [3]      <= s_bram_pre_ft_data[4];
    arrange_pre_ft_data          [4]      <= s_bram_pre_ft_data[5];
end
else if( mod6_line_wt_wide[1]==1 )begin
    arrange_pre_ft_data          [0]      <= s_bram_pre_ft_data[2];
    arrange_pre_ft_data          [1]      <= s_bram_pre_ft_data[3];
    arrange_pre_ft_data          [2]      <= s_bram_pre_ft_data[4];
    arrange_pre_ft_data          [3]      <= s_bram_pre_ft_data[5];
    arrange_pre_ft_data          [4]      <= s_bram_pre_ft_data[0];
end
else if( mod6_line_wt_wide[2]==1 )begin
    arrange_pre_ft_data          [0]      <= s_bram_pre_ft_data[3];
    arrange_pre_ft_data          [1]      <= s_bram_pre_ft_data[4];
    arrange_pre_ft_data          [2]      <= s_bram_pre_ft_data[5];
    arrange_pre_ft_data          [3]      <= s_bram_pre_ft_data[0];
    arrange_pre_ft_data          [4]      <= s_bram_pre_ft_data[1];
end
else if( mod6_line_wt_wide[3]==1 )begin
    arrange_pre_ft_data          [0]      <= s_bram_pre_ft_data[4];
    arrange_pre_ft_data          [1]      <= s_bram_pre_ft_data[5];
    arrange_pre_ft_data          [2]      <= s_bram_pre_ft_data[0];
    arrange_pre_ft_data          [3]      <= s_bram_pre_ft_data[1];
    arrange_pre_ft_data          [4]      <= s_bram_pre_ft_data[2];
end
else if( mod6_line_wt_wide[4]==1 )begin
    arrange_pre_ft_data          [0]      <= s_bram_pre_ft_data[5];
    arrange_pre_ft_data          [1]      <= s_bram_pre_ft_data[0];
    arrange_pre_ft_data          [2]      <= s_bram_pre_ft_data[1];
    arrange_pre_ft_data          [3]      <= s_bram_pre_ft_data[2];
    arrange_pre_ft_data          [4]      <= s_bram_pre_ft_data[3];
end
else if( mod6_line_wt_wide[5]==1 )begin
    arrange_pre_ft_data          [0]      <= s_bram_pre_ft_data[0];
    arrange_pre_ft_data          [1]      <= s_bram_pre_ft_data[1];
    arrange_pre_ft_data          [2]      <= s_bram_pre_ft_data[2];
    arrange_pre_ft_data          [3]      <= s_bram_pre_ft_data[3];
    arrange_pre_ft_data          [4]      <= s_bram_pre_ft_data[4];
end
```

circular data align line control

영상데이터와 필터계수의 convoluton을 위해 먼저 5개의 line을 저장할 5개의 bram을 설정

임시 write buffer 역할을 할 bram 1개를 설정

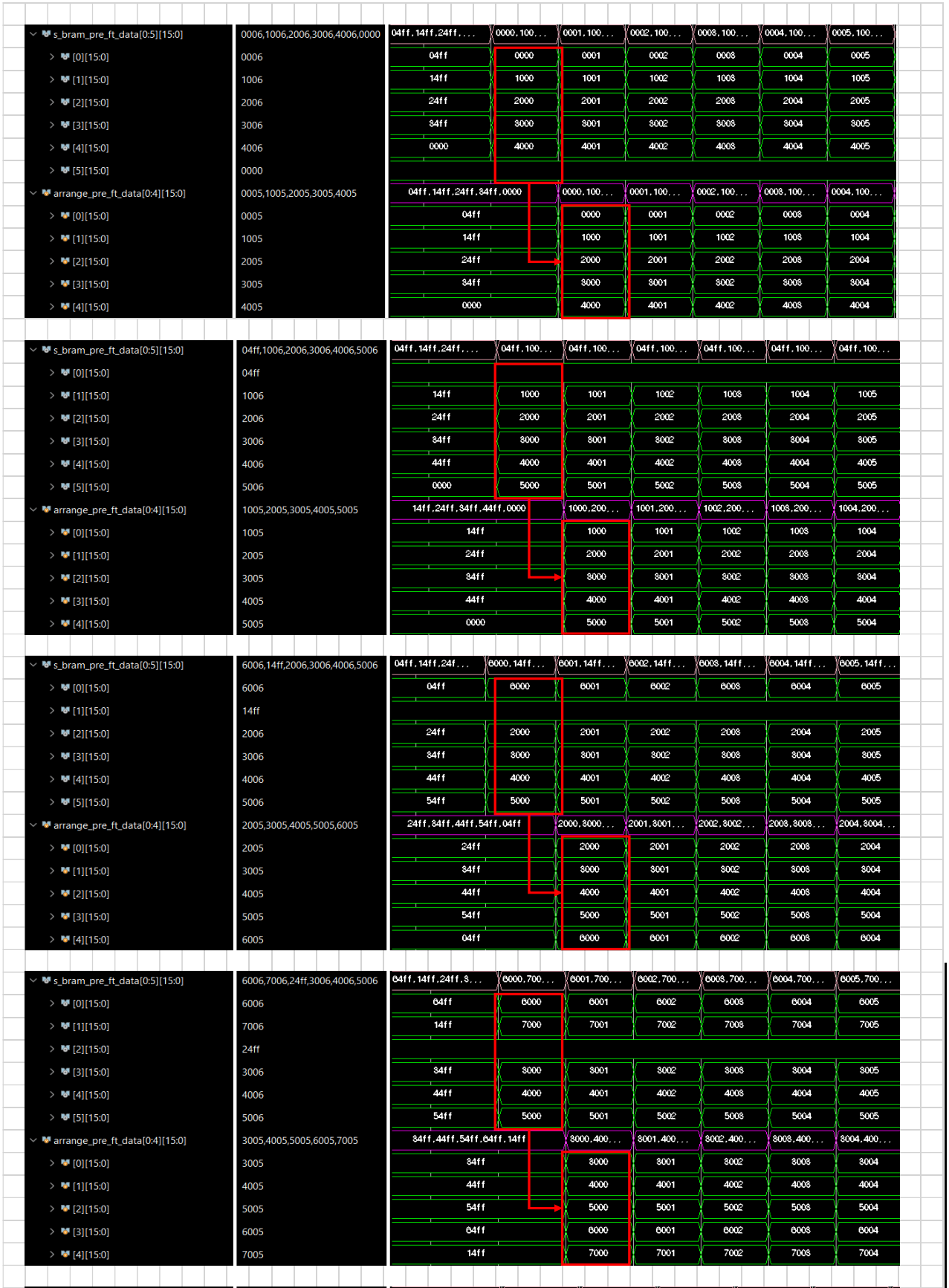
총 6개의 bram을 circular 형태로 사용하여 5개 line의 영상데이터를 한 line씩 이동하면서 출력

총 6개의 bram 중에 1개 bram(write buffer bram)에 최신 1line data 를 write

write 하고 있는 1개의 write buffer bram을 제외한 나머지 5개 bram(reading filter bram)에서 data 를 read

write 가 진행되고 있는 bram 을 제외한 5개의 bram(reading filter bram) 값을

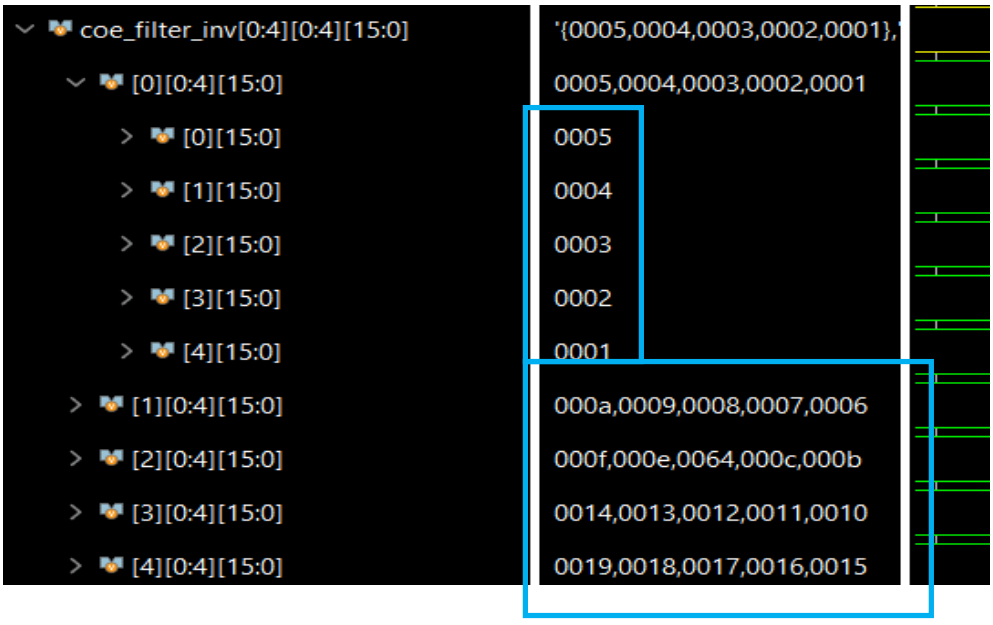
순서대로 재배열 하여 1차원 배열 인덱스에 각각 write


s_bram_pre_ft_data[0:5][15:0]
0006,1006,2006,3006,4006,0000
04ff,14ff,24ff,...
0000,100...
0001,100...
0002,100...
0003,100...
0004,100...
0005,100...
[0][15:0]
0006
04ff 0000 0001 0002 0003 0004 0005
[1][15:0]
1006
14ff 1000 1001 1002 1003 1004 1005
[2][15:0]
2006
24ff 2000 2001 2002 2003 2004 2005
[3][15:0]
3006
34ff 3000 3001 3002 3003 3004 3005
[4][15:0]
4006
0000 4000 4001 4002 4003 4004 4005
[5][15:0]
0000
arrange_pre_ft_data[0:4][15:0]
0005,1005,2005,3005,4005
04ff,14ff,24ff,34ff,0000
0000,100...
0001,100...
0002,100...
0003,100...
0004,100...
[0][15:0]
0005
04ff 0000 0001 0002 0003 0004
[1][15:0]
1005
14ff 1000 1001 1002 1003 1004
[2][15:0]
2005
24ff 2000 2001 2002 2003 2004
[3][15:0]
3005
34ff 3000 3001 3002 3003 3004
[4][15:0]
4005
0000 4000 4001 4002 4003 4004
s_bram_pre_ft_data[0:5][15:0]
04ff,1006,2006,3006,4006,5006
04ff,14ff,24ff,...
04ff,100...
04ff,100...
04ff,100...
04ff,100...
04ff,100...
04ff,100...
[0][15:0]
04ff
[1][15:0]
1006
14ff 1000 1001 1002 1003 1004 1005
[2][15:0]
2006
24ff 2000 2001 2002 2003 2004 2005
[3][15:0]
3006
34ff 3000 3001 3002 3003 3004 3005
[4][15:0]
4006
44ff 4000 4001 4002 4003 4004 4005
[5][15:0]
5006
0000 5000 5001 5002 5003 5004 5005
arrange_pre_ft_data[0:4][15:0]
1005,2005,3005,4005,5005
14ff,24ff,34ff,44ff,0000
1000,200...
1001,200...
1002,200...
1003,200...
1004,200...
[0][15:0]
1005
14ff 1000 1001 1002 1003 1004
[1][15:0]
2005
24ff 2000 2001 2002 2003 2004
[2][15:0]
3005
34ff 3000 3001 3002 3003 3004
[3][15:0]
4005
44ff 4000 4001 4002 4003 4004
[4][15:0]
5005
0000 5000 5001 5002 5003 5004
s_bram_pre_ft_data[0:5][15:0]
6006,14ff,2006,3006,4006,5006
04ff,14ff,24f...
6000,14ff...
6001,14ff...
6002,14ff...
6003,14ff...
6004,14ff...
6005,14ff...
[0][15:0]
6006
04ff 6000 6001 6002 6003 6004 6005
[1][15:0]
14ff
[2][15:0]
2006
24ff 2000 2001 2002 2003 2004 2005
[3][15:0]
3006
34ff 3000 3001 3002 3003 3004 3005
[4][15:0]
4006
44ff 4000 4001 4002 4003 4004 4005
[5][15:0]
5006
54ff 5000 5001 5002 5003 5004 5005
arrange_pre_ft_data[0:4][15:0]
2005,3005,4005,5005,6005
24ff,34ff,44ff,54ff,04ff
2000,3000...
2001,3001...
2002,3002...
2003,3003...
2004,3004...
[0][15:0]
2005
24ff 2000 2001 2002 2003 2004
[1][15:0]
3005
34ff 3000 3001 3002 3003 3004
[2][15:0]
4005
44ff 4000 4001 4002 4003 4004
[3][15:0]
5005
54ff 5000 5001 5002 5003 5004
[4][15:0]
6005
04ff 6000 6001 6002 6003 6004
s_bram_pre_ft_data[0:5][15:0]
6006,7006,24ff,3006,4006,5006
64ff,14ff,24ff,3...
6000,700...
6001,700...
6002,700...
6003,700...
6004,700...
6005,700...
[0][15:0]
6006
64ff 6000 6001 6002 6003 6004 6005
[1][15:0]
7006
14ff 7000 7001 7002 7003 7004 7005
[2][15:0]
24ff
[3][15:0]
3006
34ff 3000 3001 3002 3003 3004 3005
[4][15:0]
4006
44ff 4000 4001 4002 4003 4004 4005
[5][15:0]
5006
54ff 5000 5001 5002 5003 5004 5005
arrange_pre_ft_data[0:4][15:0]
3005,4005,5005,6005,7005
34ff,44ff,54ff,64ff,14ff
3000,400...
3001,400...
3002,400...
3003,400...
3004,400...
[0][15:0]
3005
34ff 3000 3001 3002 3003 3004
[1][15:0]
4005
44ff 4000 4001 4002 4003 4004
[2][15:0]
5005
54ff 5000 5001 5002 5003 5004
[3][15:0]
6005
64ff 6000 6001 6002 6003 6004
[4][15:0]
7005
14ff 7000 7001 7002 7003 7004

filter coe multi

영상데이터와 필터계수를 convolution을 하기 위해 필터계수를 재배열.
. 일차원배열 중 큰 인수가 가장 과거의 값으로 설정

```
else begin
    coe_filter                  [0][0]  <= 1;
    coe_filter                  [0][1]  <= 2;
    coe_filter                  [0][2]  <= 3;
    coe_filter                  [0][3]  <= 4;
    coe_filter                  [0][4]  <= 5;
    coe_filter                  [1][0]  <= 6;
    coe_filter                  [1][1]  <= 7;
    coe_filter                  [1][2]  <= 8;
    coe_filter                  [1][3]  <= 9;
    coe_filter                  [1][4]  <= 10;
    coe_filter                  [2][0]  <= 11;
    coe_filter                  [2][1]  <= 12;
    coe_filter                  [2][2]  <= 100;
    coe_filter                  [2][3]  <= 14;
    coe_filter                  [2][4]  <= 15;
    coe_filter                  [3][0]  <= 16;
    coe_filter                  [3][1]  <= 17;
    coe_filter                  [3][2]  <= 18;
    coe_filter                  [3][3]  <= 19;
    coe_filter                  [3][4]  <= 20;
    coe_filter                  [4][0]  <= 21;
    coe_filter                  [4][1]  <= 22;
    coe_filter                  [4][2]  <= 23;
    coe_filter                  [4][3]  <= 24;
    coe_filter                  [4][4]  <= 25;
end
```



영상데이터와 필터계수를 convolution을 하기 위해 영상데이터를
1clock씩 5회 delay 시켜 각각 array register 인덱스에 저장.
가장 큰 인덱스에 가장 과거의 값을 가지게 설정

```
generate
for(j=0; j < 5; j=j+1) begin: gen_pre_ft_data_conv_j
    for(i=0; i < 5; i=i+1) begin: gen_i
    delay_data  #(
        .BIT_WIDTH      (16                                 ),
        .NUM_DELAY      (i+1                                )
        )
        vf_d3_val_delay_data                                (
        .aclk           (aclk                               ),
        .delay_array_i  (arrange_pre_ft_data        [j]     ),
        .delay_array_o  (arrange_pre_ft_data_conv   [j] [i] ),
        .aresetn        (aresetn                            )
    );
    end
end
endgenerate
```

convolution을 위해 재배열된 영상데이터와 필터계수의 각각 25개 팩터를 곱함

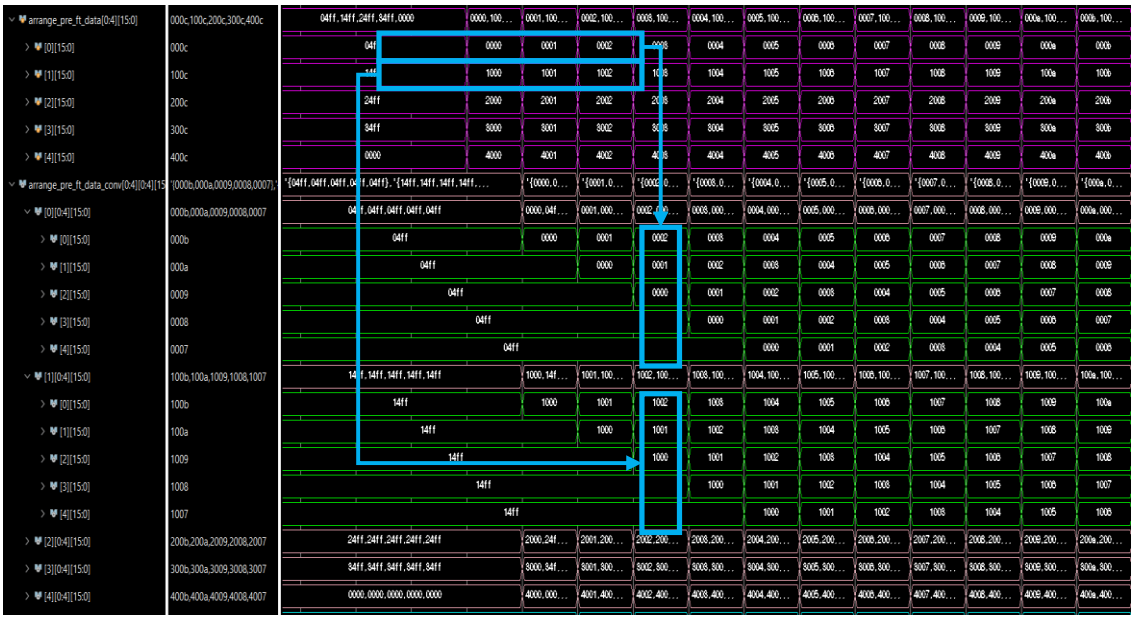
```
generate
for(j=0; j < 5; j=j+1) begin: gen_mult_filter_j
    for(i=0; i < 5; i=i+1) begin: gen_i
    mult_filter mult_filter (
        .CLK    (aclk                               ),
        .A      (arrange_pre_ft_data_conv   [j] [i] ),
        .B      (coe_filter_inv             [j] [i] ),
        .P      (mult_ft_data               [j] [i] )
    );
    end
end
endgenerate
```

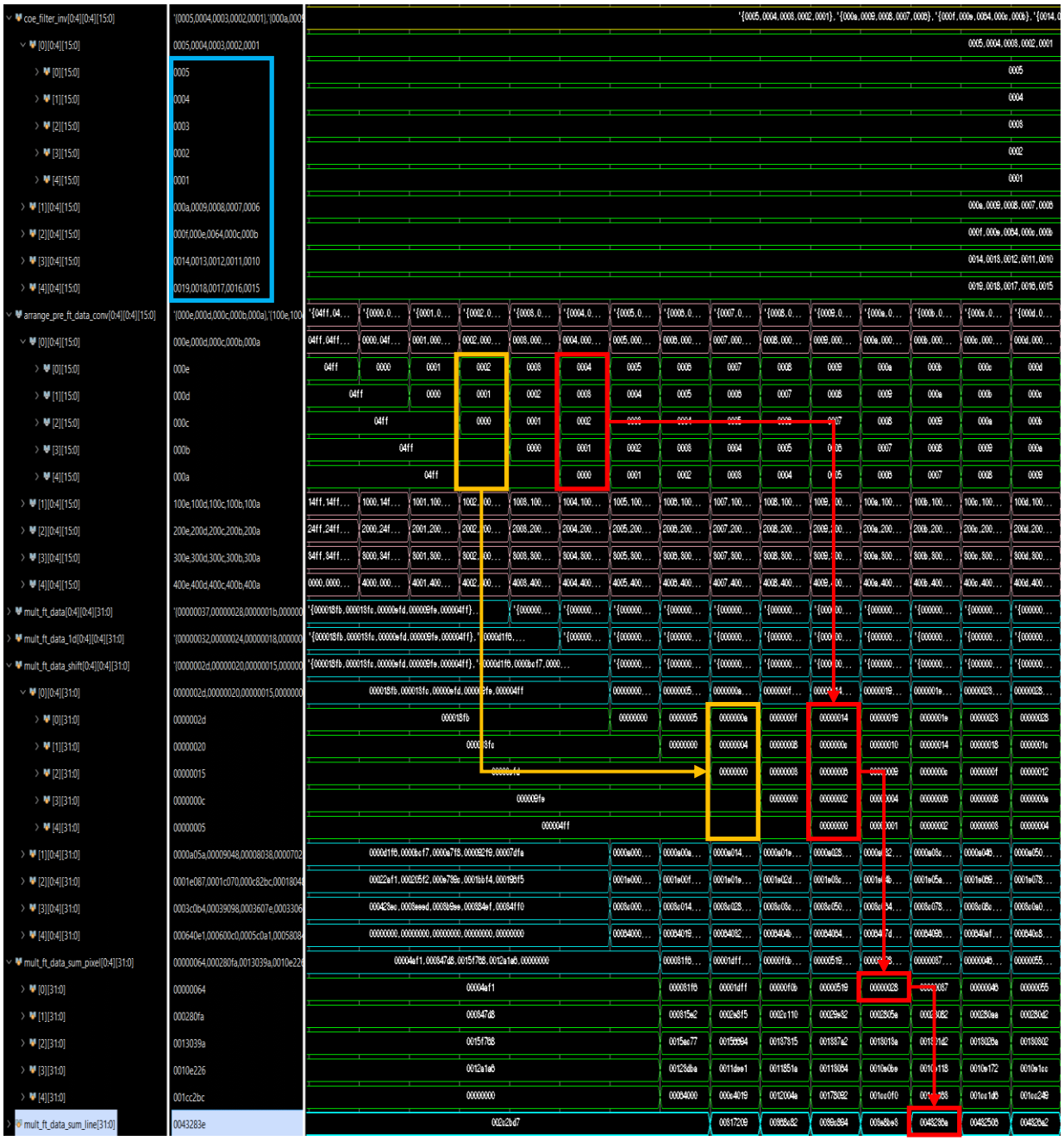
convolution된 5개 pixel array의 영상데이터를 합하여 한 라인의 값으로 합함.
각각 pixel 별로 합해진 5개의 Line을 더함.

```
generate
for(j=0; j < 5; j=j+1) begin: gen_coe_filter_inv
    for(i=0; i < 5; i=i+1) begin: gen_i
    always @(posedge aclk or negedge aresetn) begin
        if (aresetn==1'b0) begin
            coe_filter_inv                  [j][i]  <= 0;
        end
        else begin
            coe_filter_inv                  [j][i]  <= coe_filter   [j][4-i]
        end
    end
    end
end
endgenerate
```

```
generate
for(j=0; j < 5; j=j+1) begin: gen_mult_ft_data_sum_pixel
always @(posedge aclk or negedge aresetn) begin
    if (aresetn==1'b0) begin
        mult_ft_data_sum_pixel      [j]     <= 0;
    end
    else begin
        mult_ft_data_sum_pixel      [j]
        <= mult_ft_data_shift[j][0] + mult_ft_data_shift[j][1] + mult_ft_data_shift[j][2] + mult_ft_data_shift[j][3] + mult_ft_data_shift[j][4];
    end
end
end
endgenerate

always @(posedge aclk or negedge aresetn) begin
    if (aresetn==1'b0) begin
        mult_ft_data_sum_line       [31:0]  <= 0;
    end
    else begin
        mult_ft_data_sum_line
        <= mult_ft_data_sum_pixel[0] + mult_ft_data_sum_pixel[1] + mult_ft_data_sum_pixel[2] + mult_ft_data_sum_pixel[3] + mult_ft_data_sum_pixel[4];
    end
end
```




coe_filter_inv[0:4][0:4][15:0]
[0][0:4][15:0]
[0][15:0]
[1][15:0]
[2][15:0]
[3][15:0]
[4][15:0]
[1][0:4][15:0]
[2][0:4][15:0]
[3][0:4][15:0]
[4][0:4][15:0]
arrange_pre_ft_data_conv[0:4][0:4][15:0]
mult_ft_data[0:4][0:4][31:0]
mult_ft_data_1d[0:4][0:4][31:0]
mult_ft_data_shift[0:4][0:4][31:0]
mult_ft_data_sum_pixel[0:4][31:0]
mult_ft_data_sum_line[31:0]
0005,0004,0003,0002,0001
000a,0009,0008,0007,0006
000f,000e,0064,000c,000b
0014,0013,0012,0011,0010
0019,0018,0017,0016,0015
000e,000d,000c,000b,000a
100e,100d,100c,100b,100a
200e,200d,200c,200b,200a
300e,300d,300c,300b,300a
400e,400d,400c,400b,400a
0000002d,00000020,00000015,0000000c,00000005
0000a05a,00009048,00008038,00007028,00006018
0001e087,0001c070,000c82bc,00018048,00010030
0003c0b4,00039098,0003607e,00033060,00030048
000640e1,0006000c0,0005c0a1,0005808c,00054078
00000064,000280fa,0013039a,0010e226,001cc2bc
0043283e
0005,0004,0003,0002,0001
000a,0009,0008,0007,0006
000f,000e,0064,000c,000b
0014,0013,0012,0011,0010
0019,0018,0017,0016,0015
000e,000d,000c,000b,000a
100e,100d,100c,100b,100a
200e,200d,200c,200b,200a
300e,300d,300c,300b,300a
400e,400d,400c,400b,400a
0000002d,00000020,00000015,0000000c,00000005
0000a05a,00009048,00008038,00007028,00006018
0001e087,0001c070,000c82bc,00018048,00010030
0003c0b4,00039098,0003607e,00033060,00030048
000640e1,0006000c0,0005c0a1,0005808c,00054078
00000064,000280fa,0013039a,0010e226,001cc2bc
0043283e

StandardHD

	blank		active		blank		blank		active		blank		active_L	total_L	H_level	L_level
Field	1		1		2		2		2		1					
1080p	1	41	42	1121	1122	1125									3FB	4
		41		1080		4							1080	1125	FE	1
1080i	1	20	21	560	561	563	564	583	584	1123	1124	1125			3FB	4
		20		540		3		20		540		2	1080	1125	FE	1
Pal	1	22	23	310	311	332	333	335	336	623	624	625				
		22		288		22		3		288		2	576	625	F0	10
NTSC	1	21	22	261	262	282	283	284	285	524	525	525				
		21		240		21		2		240		1	480	525	F0	10

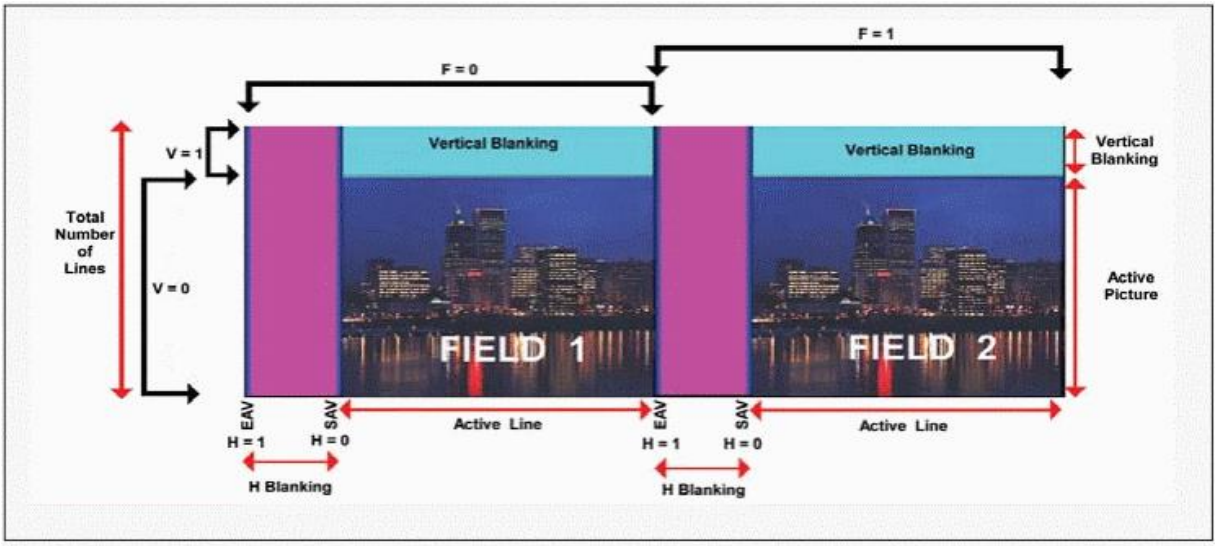


Figure 12. Layout of 2:1 interlaced digital frame.

	Field Line	525 Line	625 Line	1080P Line	1080i Line	1035i Line	720P	SAV	EAV	9	F	V	H	P3	P2	P1	P0	1	0
Active Video	1	20-236	23-310	42-1121	21-560	41-557	26-745	200		1	0	0	0	0	0	0	0	0	0
									274	0	0	1	1	1	0	1	0	0	
Field Blanking	1	4-19,	1-22,	1-41,	1-20,	1-40,	1-25,	2AC		1	0	1	0	1	0	1	1	0	0
		264-265	311-312	1122-1125	561-563	558-563	746-750		2D8	1	0	1	1	0	1	1	0	0	0
Active Video	2	283-525	336-623	NA	584-1123	603-1120	NA	31C		1	1	0	0	0	1	1	1	0	0
									368	1	0	1	1	0	1	0	0	0	
Field Blanking	2	1-3,	624-625,	NA	1124-1125,	1121-1125,	NA	3B0		1	1	1	0	1	1	0	0	0	0
		266-282	313-335		564-583	564-602			3C4	1	1	1	1	0	0	0	1	0	0