



DWT (210) 가 DWT (200), 가 DWT (220) DWT  
 DWT 가  
 DWT 가 DWT 가  
 DWT 가  
 DWT 가

2

, DWT, , LCD

g) (up - scaling) (up - samplin

(resize) 가  
 (scale up up - sample)  
 M (rows) N (columns)  
 R S 가 ( , RM / SN).  
 LCD (resolution) , CRT LCD , CRT  
 가 , CRT , 640 × 480 , L  
 CD (blurred)

가 ( ) 가 , 가 가 , LCD  
 (blocking) 가 LCD 가 가 100 × 100 .  
 가 1/4 가 200 × 200 , 가  
 , 2:1 가 .

가 , (duplicate) , 2:1  
 가 3 " (fill)" 2 x 2 4 가  
 가 (discernible) , 가 (squares)  
 fuzzier), , (blocky) , 가 (edge features)

가 가 (bi - linear interpolation)  
 2:1 , 4

$$X_A X_B X_C \dots$$

$$X_D X_E X_F \dots$$

...

2

$$X_A \frac{X_A+X_B}{2} X_B \frac{X_B+X_C}{2} X_C \dots$$

$$\frac{X_A+X_D}{2} \frac{X_A+X_B+X_D+X_E}{4} \dots$$

$$X_D \frac{X_D+X_E}{2} X_E \dots$$

가 M x N , (filling) , M\*N\*4 (b)  
 lurred details)

, DWT (Discrete Wavelet Transform)  
 , 가 DWT

가 (virtual) DWT  
 , DWT

가

가 , 가 , DWT , DWT , 가 DWT 가 , 가 , DWT DWT ,

1 (forward) DWT

2 DWT

3 DWT

4a DWT

4b 1 DWT

4c 5

5

6

7

ate) DWT 1 "가" (approxim  
 rete Cosine Transform) . DWT (sinusoidal basis functions) DWT DCT(Disc  
 " (discrete)" , DWT " (basis)"  
 , (jagged) . DWT , DWT  
 (well - defined coefficients) (Wavelet coefficients)  
 (bi - orthogonal spline filters) DWT . DWT DWT 9 - 7 , DWT VLS

가 DWT , DWT 가 DWT

, DWT -

2 DWT (H) (L) 4 LL, LH, HL HH 4 DWT DWT 1/4 DWT "LL" DWT LL (1 - DWT) 1/4 가 DWT

DWT k 4 LL<sub>k</sub>, HL<sub>k</sub>, LH<sub>k</sub>, HH<sub>k</sub> DWT LL<sub>k-1</sub> DWT LL<sub>k</sub> LH<sub>k</sub>, HL<sub>k</sub> HH<sub>k</sub> LL<sub>k</sub>

, K (K=1 , LL<sub>0</sub> )

LL<sub>k</sub> - LL<sub>k-1</sub> 1/4

LH<sub>k</sub> - LL<sub>k-1</sub>

HL<sub>k</sub> - LL<sub>k-1</sub>

HH<sub>k</sub> - LL<sub>k-1</sub>

LL<sub>k</sub> DWT DWT 가 DWT (multi - resolution hierarchical decomposition) (unitary transformation) " (forward)" DWT DWT LL

, DWT LL DWT가

4

1 DWT

2 DWT - DWT - , 1  
 LL 가 M N , 1  
 M\*N LL LL<sub>v</sub> ( 200). , M\*N 가 가  
 LH<sub>v</sub>, HL<sub>v</sub> HH<sub>v</sub> 가 ( 210). (cons  
 truct) 가 , ( , HL, LH HH  
 ) / , 가 - (non-zero)  
 , 가 LH<sub>v</sub>, HL<sub>v</sub> HH<sub>v</sub> . 9-7  
 DWT , LL 가 DWT 가 DWT  
 ( )  
 , LL<sub>v</sub>, LH<sub>v</sub>, HL<sub>v</sub> HH<sub>v</sub> , 2 DWT가 .  
 , M\*2 N\*2 , 가

3 DWT - DWT - M N  
 1 2 2 . M N  
 \*N i,j , i 1-M , .  
 j 1-N , 1 1,1 , l<sub>1,2</sub> , , 2  
 l<sub>2,1</sub> , l<sub>2,2</sub> , 가 , l 가  
 (virtual sub - band) LL<sub>v</sub> . (constructed) 가 가  
 ( DWT ),  
 , 가 4  
 M\*2 N\*2 , 2 DWT  
 U I (clarity) (perception)  
 M\*2 N\*2 U 가  
 2 DWT U<sub>r,s</sub> ,  
 r 1-M\*2 , s 1-N\*2 .  
 U<sub>r,s</sub> l 2:1 .

4a DWT . 1 DWT 4b  
 c가 ( D<sub>k</sub>(400) 4a , 4a ,  
 , q<sub>k</sub> DWT 가 , L<sub>k</sub> = (p<sub>k</sub>+q<sub>k</sub>)\*c L<sub>k</sub>가 . L<sub>k</sub>  
 , p<sub>k-1</sub> , p<sub>k</sub> , p<sub>k-1</sub> .  
 p<sub>k</sub> " p<sub>k-1</sub> D<sub>k</sub> D<sub>k-1</sub> , p<sub>k</sub> p<sub>k-1</sub> "  
 . 4a (400) 4b DWT DWT  
 가 . DWT

4b 1 DWT DWT 1 2  
 1 DWT ( ) 2 , LFS(Low Frequenc  
 y Sub - band) HFS(High Frequency Sub - band) . 1 DWT - ,  
 M N/2 2 가 .  
 DWT LFS (skinny)  
 DWT LFS . 2  
 1 DWT 가 , 2 DWT가 가 , DWT ,  
 - DWT - DWT가 2 DWT , ( )

used) . . . . . 1 DWT , 5 , - DWT (transp  
 . . . . . 1 DWT 가 LL ( ) 2:1  
 , 2 DWT 4b 1 DWT

DWT ,  $U_{r,s}$  ,  $U_i$ 가 가 1  
 ,  $a_n$  (가 ) LFS ,  $c_n$  (가 ) HFS  $U_i$

$$U_i = \sum_n [\bar{h}_{2n-i} a_n + \bar{g}_{2n-i} c_n] = \sum_n \bar{h}_{2n-i} a_n + \sum_n \bar{g}_{2n-i} c_n$$

LFS 가 LL<sub>v</sub> LH<sub>v</sub> , HFS 가 HL<sub>v</sub>  
 HH<sub>v</sub> . . . . . 9 - 7 - DWT 4a  
 ( , )  $\bar{x}_k$   $\bar{z}_k$  . DWT , 1996

12 17 08/767,976, "An Integrated Systolic Architecture for Decomposition and R  
 econstruction of Signals Using Wavelet Transforms" .  $U_i$

$$U_i^{(1)} = \sum_n \bar{h}_{2n-i} a_n, \quad U_i^{(2)} = \sum_n \bar{g}_{2n-i} c_n$$

$U_i^{(1)}$   $U_i^{(2)}$  , ,  $j=0,1,\dots,n/2 - 1$   $U'_{2j} (1)$   $U'_{2j} (2)$

$$\begin{aligned} U_0^{(1)} &= \bar{h}_0 a_0 + \bar{h}_2 a_1, & U_0^{(2)} &= \bar{g}_0 c_0 + \bar{g}_2 c_1 + \bar{g}_4 c_2, \\ U_2^{(1)} &= \bar{h}_{-2} a_0 + \bar{h}_0 a_1 + \bar{h}_2 a_2, & U_2^{(2)} &= \bar{g}_{-2} c_0 + \bar{g}_0 c_1 + \bar{g}_2 c_2 + \bar{g}_4 c_3, \\ U_4^{(1)} &= \bar{h}_{-2} a_1 + \bar{h}_0 a_2 + \bar{h}_2 a_3, & U_4^{(2)} &= \bar{g}_{-2} c_1 + \bar{g}_0 c_2 + \bar{g}_2 c_3 + \bar{g}_4 c_4, \\ &\vdots & &\vdots \\ U_{n-6}^{(1)} &= \bar{h}_{-2} a_{n/2-4} + \bar{h}_0 a_{n/2-3} + \bar{h}_2 a_{n/2-2}, & & \\ U_{n-6}^{(2)} &= \bar{g}_{-2} c_{n/2-4} + \bar{g}_0 c_{n/2-3} + \bar{g}_2 c_{n/2-2} + \bar{g}_4 c_{n/2-1}, & & \\ U_{n-4}^{(1)} &= \bar{h}_{-2} a_{n/2-3} + \bar{h}_0 a_{n/2-2} + \bar{h}_2 a_{n/2-1}, & U_{n-4}^{(2)} &= \bar{g}_{-2} c_{n/2-3} + \bar{g}_0 c_{n/2-2} + \bar{g}_2 c_{n/2-1}, \\ U_{n-2}^{(1)} &= \bar{h}_{-2} a_{n/2-2} + \bar{h}_0 a_{n/2-1}, & U_{n-2}^{(2)} &= \bar{g}_{-2} c_{n/2-2} + \bar{g}_0 c_{n/2-1}. \end{aligned}$$

9 - 7

DWT

가  $h_n = h_{-n}$  가  $\bar{x}_n = (-1)^n h_{1-n}$  ,  $h_k$  DWT ,  
 $n=0$  ,  $\bar{x}_0 = h_{-1}$  .  $n=2$  ,  $\bar{x}_2 = h_1$   $h_{-1} = \bar{x}_0$  ,  $\bar{x}_2 = \bar{x}_0$  .  
 가  $n=4$  ,  $\bar{x}_4 = h_3 = \bar{x}_{-2}$  .  $\bar{x}_2 = \bar{x}_{-2}$   $\bar{x}_n = \bar{x}_{-n}$  가 .  
 $U'_{2j}$  4  $\bar{x}_0, \bar{x}_2, \bar{x}_2, \bar{x}_4$  5  $\bar{x}_3, \bar{x}_1, \bar{x}_5, \bar{x}_3, \bar{x}_1$  가  $U'_{2j}$ -

DWT가

DWT

4b

1

2

$a_i$

$c_i$

2

5

4

$U'_{1}, U'_{3}, U'_{5} \dots$

$U'_{0}, U'_{2}, U'_{4} \dots$

가

DWT

(402)

(452)

2

(300)

(HFS)(410)

(L

FS)(420) 2

HFS

(410)

가

2

(415, 417)

(415, 417, 425, 427)

4a

, 2

가

(400)

(415)  $a_i$ 가

(417)

가

$\bar{x}_2$

가

(420)

(425)  $\bar{x}_4$

$c_i$

가 /

(430)

(417)

(412)가

, 1

0

$a_{i-1}$

$i=0$  ,  $a_0$

(412)

,  $c_0$

(422)

$a_0$   $c_0$

(415

425)

, 가 /

(430)

$x_0$

, -

$i=0$  ,

(412, 424, 422)

(417 427) 0

$i=0$  ,

(412)  $a_0$

(417)  $p_i$

,  $a_i$

(412)

(415)

, (415)  $\bar{x}_2 a_i$

(417)  $\bar{x}_0 a_0$

가 /

(430)

,  $i=2$

( )

$i=1$  ,

(425, 427)  $c_1$

$c_0$  2  $\bar{x}_1$

, 1

$U'_{0}$ 가

$c_2$

, 가 /

(430)

3

,  $i=2$  ,

(424)  $c_0$

(427) ( )

$p_i$

, (422)  $c_i$

(427) ( $q_i$   $p_i$

4a

)  $q_i$

, (427) ( $c_1 +$

$c_0$ )  $\bar{x}_2$

, (415, 417)

가 /

(430)

$i=2$  ,

(425, 427)

가

,  $i=2$  ,

(415, 417)

( $a_0 + a_2$ )  $\bar{x}_2$

$a_1$   $\bar{x}_1$

,  $c_2$

( $c_0 + c_1$ )<sup>\*</sup> 2

$i=2$  (425,

427)

$0a_0$

$\bar{x}_2 a_i$

$\bar{x}_1$

(415, 417)

가

, 가 /

(430)

1  $U'$

$0 =$

$0a_0 +$

$\bar{x}_2 a_1 +$

$c_0$

$+ c_1$

$c_2$

,  $i=2(3)$  ,  $i$  , 가 / (430) (420)  
 , (410) 가 . , 가 / (430) (410)

4c 5 (465, 467, 475, 477, 479) (450) . ( (465, 467, 475, 477, 479) 4a (400) . (462, 464, 472, 474) 가

(450) .  $i=0$  ,  $a_0$  (465) , (475)가  $c_0$   
 , (462) .  $i=1$  , (462)  $a_0$  (467) ,  
 (472) (477)  $c_0$  . ,  $i=1$  ,  $a_1$   $c_1$  (465, 475) .  $i=2$  , (465)  
 $a_2$  , (467)  $a_1$   $q_i$  ,  $p_i$  0 . , (465)  $a_2$  ~~3~~ , (467)  
 ( $a_1+a_0$ ) ~~1~~ . 가 / (480) , (475, 477, 479) 가 ,  
 .  $i=2$  , (475, 477, 479) 가 / (480) .

$i=3$  ,  $c_3$  (475) , (477) (472)  $c_2$  , (479)  
 $c_1$  , (477)  $c_0$  . , (475)  $c_3$  ~~5~~ , (477) ( $c_0$   
 $+c_2$ ) \* ~~3~~ , (479)  $c_{11}$  ~~5~~ . 가 / (48)  
 (475, 477, 479)  $i=3$  (465, 467)  $i=2$  가 , 가  
 / (480) 2 ( 1 )  $x_1 = 1a_0 + \overline{1}a_1 + \overline{3}a_2 + \overline{3}c_0 + \overline{5}c_3 + \overline{5}c_1$  ~~5~~ .

,  $i=3(4)$  ,  $i$  , 가 / (480) (475, 477, 479)  
 , (465, 467) 가 . , 가 / (480) (  $U'$   
 465, 467) , , 1 DWT . LFS HF  
 $i$ 가 , 가 4b ,  $U'_{i-1}$  1 2  
 $S$  ,  $U'_{N*2-1}$  ,  $U'$   
 $N*2$   $M*2$  ,  $N*2$  2 1 .  
 $i$ 가 0  $M*2*N*2 - 1$  ,  $U'_i$ 가 , 가  
 ,  $TU'_i$  1 , DWT , 4b  
 $U_i( U_{r,s} , - )$  .  $TU'_i$  1 DWT  
 5 .

DWT DWT 1 1 DWT LFS LL<sub>v</sub> HL<sub>v</sub> , HFS LH<sub>v</sub> HH<sub>v</sub> , 2  
 ( 505). 1 DWT LFS HFS ( 51  
 0). DWT 1 M\*N\*4 ( 4b - 4c U<sub>i</sub>)  
 ( 520). U<sub>i</sub> 가 가  
 (510) 1 DWT 가 , 가  
 DWT ( 540). (530) U<sub>i</sub>  
 가 , (U<sub>i</sub> - min)/(max - min)\*K( , min  
 , max , K ) , 8

K 255

6

6 DWT

(600) 6 , (600) / /  
 n - (610) (600)  
 " (sensing)" R,G,B  
 3 ( G1, G2가 4 ) ,  
 (610)  
 (Bayer pattern)

el)" " (pixel substitution)" (615) 가 / " (dead pix  
 . RAM(616) . RAM(616)

1 (628) DWT , JPEG(Joint Photographic Experts Group)  
 DPCM(Differential Pulse Code Modulation) . RAM(629) DWT  
 . 1 (628) / (630)  
 / (630) (Modified Huffman Coding)(R  
 AM(631) ) 2 ,  
 (640)

(670) (660) (640) , (670) DWT  
 , 4b - 4c  
 (628) DWT (670)  
 (640) (628)  
 DWT (628) (660) L

CD (on - board) (680) (670)  
(680) (670)

RAM (616, 629, 631) 가 RAM RAM  
(640) (670) 6 RAM  
가 (660) (660) RAM  
(616, 629, 631)

7 PC (710) (730) (730) (740)  
, ROM, RAM (732)  
(734) (734)  
(710) DWT (734)  
(730)가 / 가 가  
(730) 가 (732)  
(732)  
가 LCD DWT (730) (730)  
(716) DWT DWT (710)  
? 가 ( DWT (712),  
/ RAM (711) )  
730) 가 CD - ROM (718), C++ 가  
(711) (zooming)

(710) (712) (711) / (713), I/O  
(715) (714) I/O (715) (716), (718),  
I/O (717) I/O I/O 가  
가

(740) 가 (730) (732)  
(732) IC

(730) (740)

( / ) 가 (734) I/O (717) I/O (717)

(I/O (715) - (711) (714) - (713)) (718)

(712) (712) (716)

/ (712) (750) 가 (710)

(720) (730) 가 (710) 가 (710) 가

(750) , DWT (720) 가

(750)

가

(57)

1.

(Discrete Wavelet Transform)

가 DWT

가  
p - sampled)

DWT

DWT

(u

2.

1

가 LL , HL , LH HH

3.

2 ,

LH

.

4.

2 ,

HL , LH HH

.

5.

2 ,

DWT 2 DWT

.

6.

5 ,

2 DWT ,

가 - (row - wise fashion) 1 DWT ;

가 가 , 1 DWT ;

DWT 1 DWT - , 1

.

7.

2 ,

가

.

8.

;

가 , DWT ,

9.

8

1 ;

2 - , 1 2 (alternating fashion)

10.

9

1 2 ,

DWT ;

가 가

11.

10

12.

10

DWT

13.

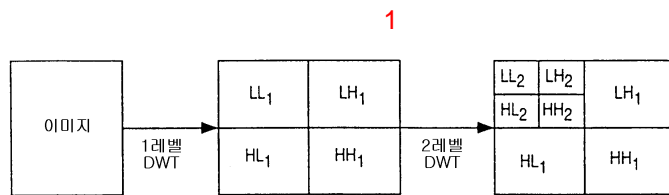
9 ,

14.

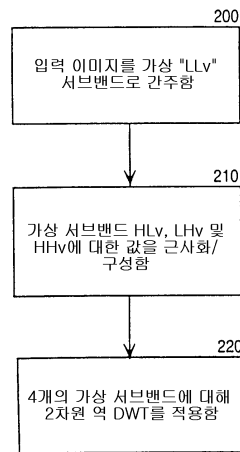
13 ,

15.

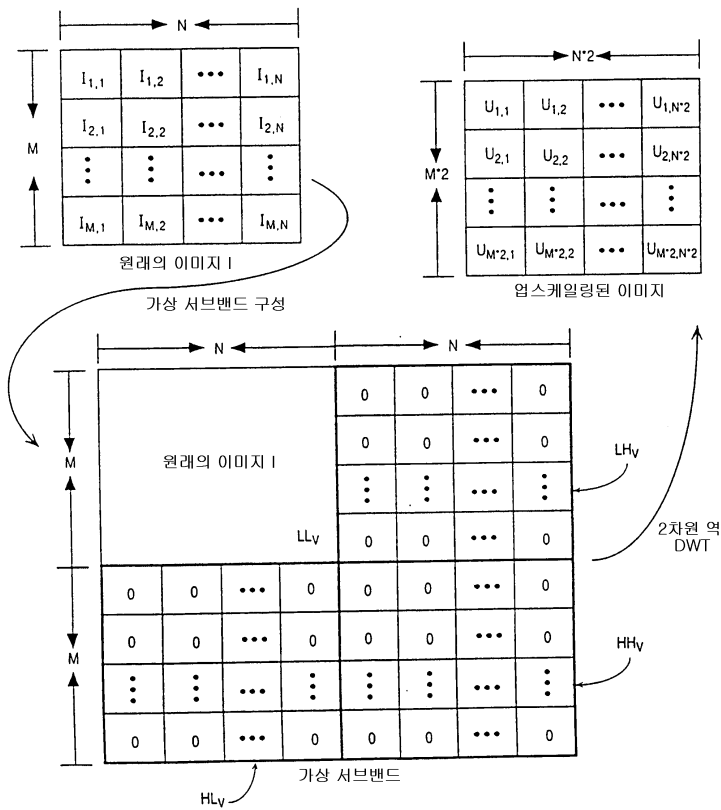
, DWT 가 DWT 가 , 가 DWT 가



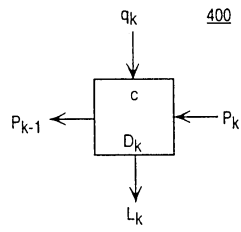
2



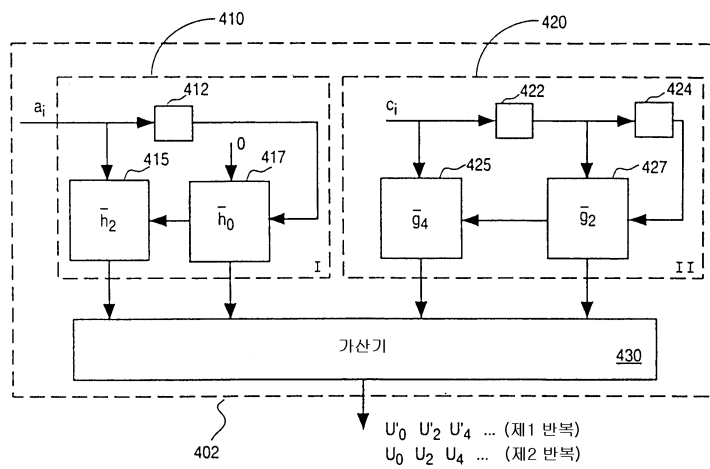
3



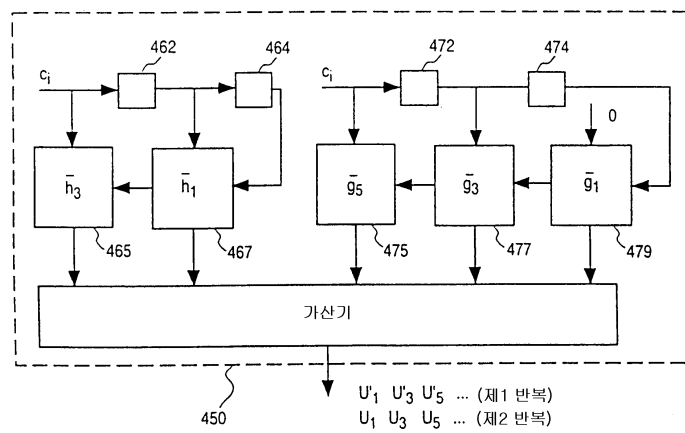
4a



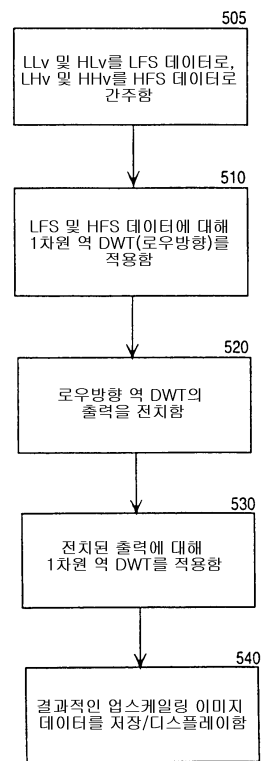
4b



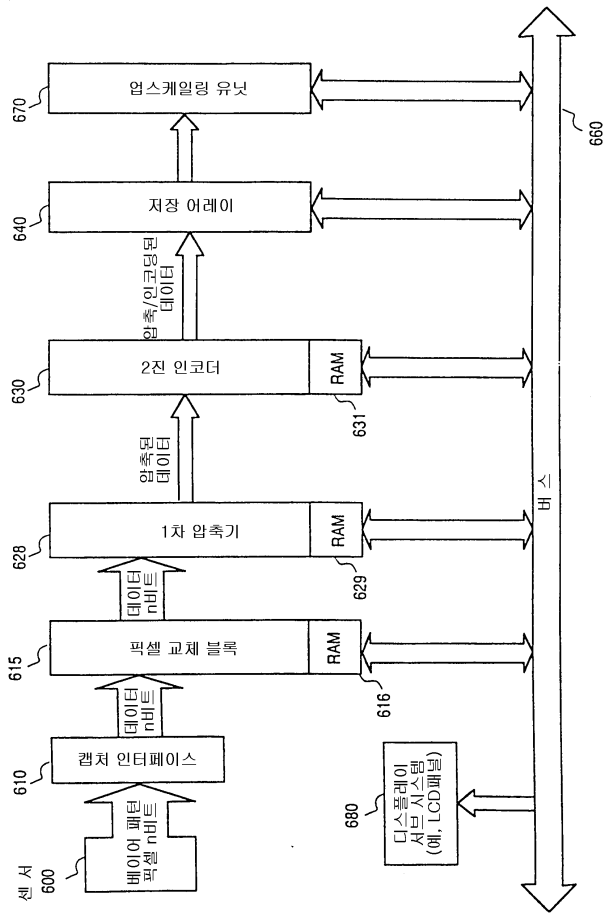
4c



5



6



7

