



Image Processing

Morphological Image Processing (Part II)

Pattern Recognition and Image Processing Laboratory (Since 2012)

Gray-Scale Morphology

Dilation and Erosion

- Definition: Dilation

$$(f \oplus b)(x, y) = \max \{ f(x - x', y - y') + b(x', y') \mid (x', y') \in D_b \}$$

“0”

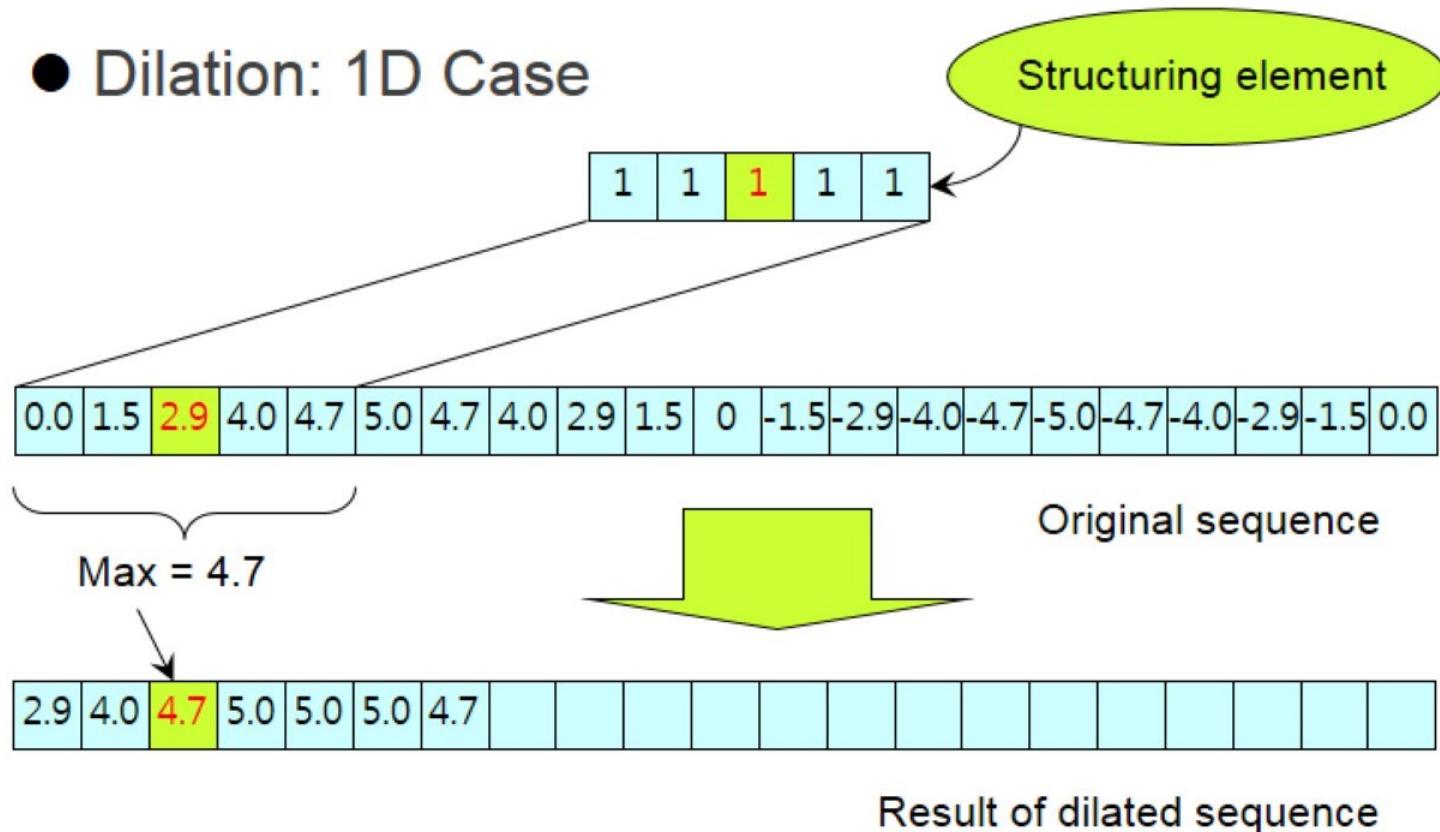
In practice,
it is simplified.

$$(f \oplus b)(x, y) = \max \{ f(x - x') \mid (x', y') \in D_b \}$$

Note: D_b denotes domain of b .

Gray-Scale Morphology

- Dilation: 1D Case



Gray-Scale Morphology

- Dilation: MATLAB sample (1D Case)

```
>> w = 0:2*pi/20:2*pi;  
>> y = 5*sin(w);  
>> se = [1 1 1 1 1];  
>> yd = imdilate(y, se); % zero padding  
>> plot(y);  
>> hold on ;  
>> plot(yd, '-r');
```

Gray-Scale Morphology

- Dilation: 2D Case

1	1	1
1	1	1
1	1	1

Structuring element

91	99	99	68	60	64	81	81	67	59
82	66	79	80	70	79	93	72	68	56
65	77	72	64	86	83	68	57	54	40
86	68	61	81	92	65	46	40	37	45
73	75	85	99	91	57	46	41	39	40
84	84	98	96	72	56	55	52	40	46
78	73	97	86	68	60	52	50	44	57
54	68	91	80	69	66	53	49	52	70
42	60	77	73	67	75	80	61	46	74
45	47	74	81	65	77	91	63	41	73

Original image

99	99	99	99	80	93	93	93	81	68
99	99	99	99	86	93	93	93	81	68
86	86	81	92	92	93	93	93	72	68
86	86	99	99	99	92	83	68	57	54
86	98	99	99	99	92	65	55	52	46
84	98	99	99	99	91	60	55	57	57
84	98	98	98	96	72	66	55	70	70
78	97	97	97	86	80	80	80	74	74
68	91	91	91	81	91	91	91	74	74
60	77	81	81	81	91	91	91	74	74

Dilated image

Gray-Scale Morphology

Dilation and Erosion

- Definition: Erosion

$$(f \ominus b)(x, y) = \min \{ f(x + x', y + y') - b(x', y') \mid (x', y') \in D_b \}$$

“0”

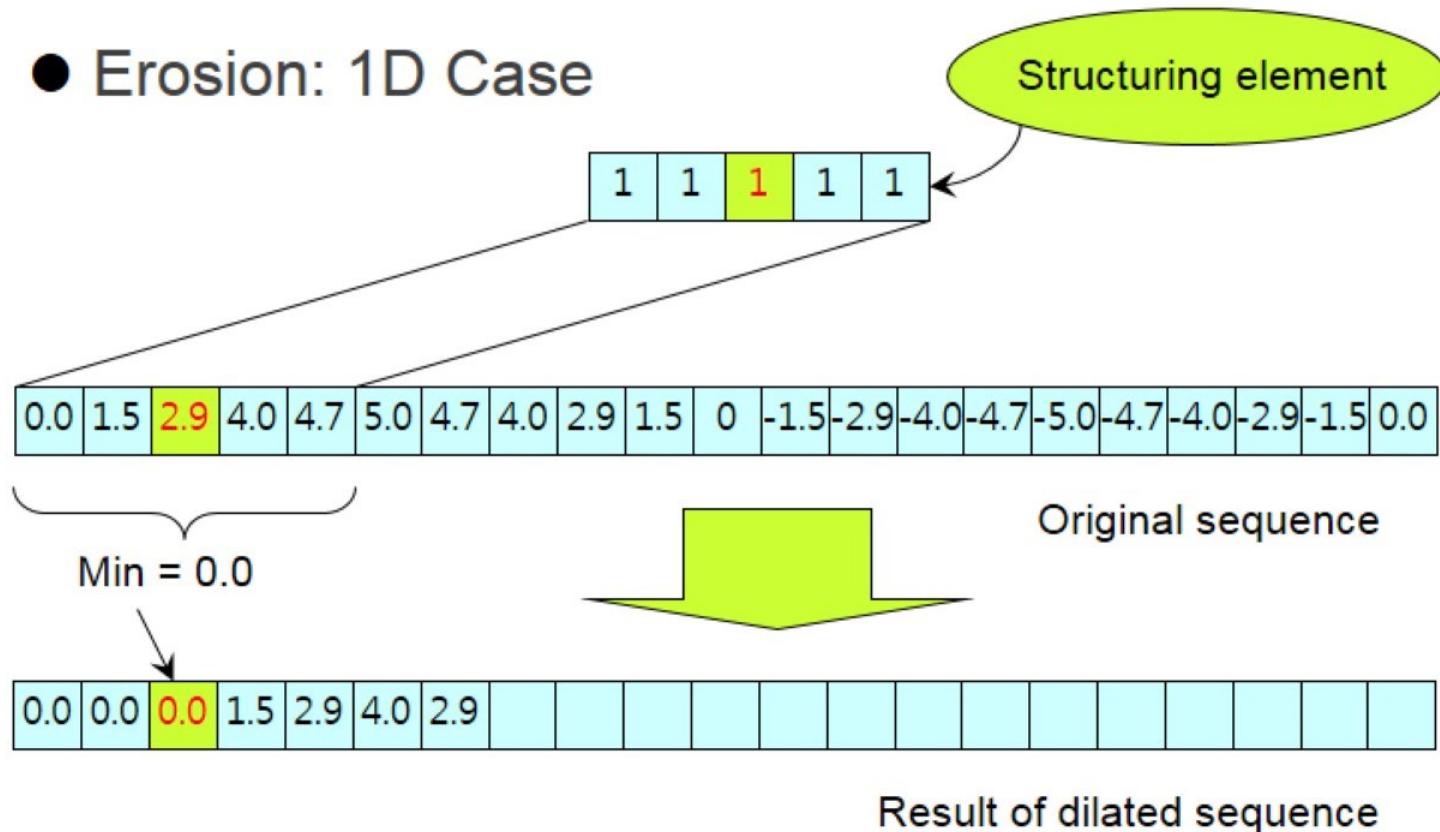
In practice,
it is simplified.

$$(f \ominus b)(x, y) = \min \{ f(x + x', y + y') \mid (x', y') \in D_b \}$$

Note: D_b denotes domain of b .

Gray-Scale Morphology

- Erosion: 1D Case



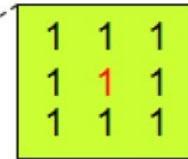
Gray-Scale Morphology

- Erosion: MATLAB sample (1D Case)

```
>> w = 0:2*pi/20:2*pi;  
>> y = 5*sin(w);  
>> se = [1 1 1 1 1];  
>> ye = imerode(y, se); % zero padding  
>> plot(y);  
>> hold on ;  
>> plot(ye, '-r');
```

Gray-Scale Morphology

- Erosion: 2D Case



Structuring element

91	99	99	68	60	64	81	81	67	59
82	66	79	80	70	79	93	72	68	56
65	77	72	64	86	83	68	57	54	40
86	68	61	81	92	65	46	40	37	45
73	75	85	99	91	57	46	41	39	40
84	84	98	96	72	56	55	52	40	46
78	73	97	86	68	60	52	50	44	57
54	68	91	80	69	66	53	49	52	70
42	60	77	73	67	75	80	61	46	74
45	47	74	81	65	77	91	63	41	73

Original image

66	66	66	60	60	60	64	67	56	56
65	65	64	60	60	60	57	54	40	40
65	61	61	61	64	46	40	37	37	37
65	61	61	61	57	46	40	37	37	37
68	61	61	61	56	46	40	37	37	37
73	73	73	68	56	46	41	39	39	39
54	54	68	68	56	52	49	40	40	40
42	42	60	67	60	52	49	44	44	44
42	42	47	65	65	53	49	41	41	41
42	42	47	65	65	65	61	41	41	41

Eroded image

Gray-Scale Morphology

Combination of Dilation and Erosion

- Definition: Morphological Gradient

$$\nabla_{mg} = (f \oplus b)(x, y) - (f \ominus b)(x, y)$$

The equation $\nabla_{mg} = (f \oplus b)(x, y) - (f \ominus b)(x, y)$ is displayed. Two terms in the equation are highlighted with green ovals: $(f \oplus b)(x, y)$ and $(f \ominus b)(x, y)$. Arrows point from the labels "Dilation" and "Erosion" respectively to these highlighted terms.

Dilation

Erosion

Gray-Scale Morphology

- Morphological Gradient: MATLAB code

```
>> f = imread('aerial.tif');
>> se = strel('square', 3);
>> gd = imdilate(f, se);
>> ge = imerode(f, se);
>> morph_grad = imsubtract(gd, ge);
>> figure(1); imshow(f);
>> figure(2); imshow(gd);
>> figure(3); imshow(ge);
>> figure(4); imshow(morph_grad);
```

Gray-Scale Morphology

Opening and Closing

- **Function:** Openings are used to remove small bright details while leaving the overall gray levels and larger bright features relatively undisturbed.
- **Definition:** Opening

$$f \circ b = (f \ominus b) \oplus b$$

Gray-Scale Morphology

Opening and Closing

- **Function:** Closings are used often in combination for image smoothing and noise removal.
They suppress dark details smaller than the structuring elements.
- **Definition:** Closing

$$f \bullet b = (f \oplus b) \ominus b$$

Gray-Scale Morphology

- Application: Smoothing using openings and closings

```
>> f = imread('dowels.tif');
>> se = strel('disk', 5);
>> fo = imopen(f, se);
>> foc = imclose(fo, se);
>> figure, imshow(f);
>> figure, imshow(fo);
>> figure, imshow(foc);
```

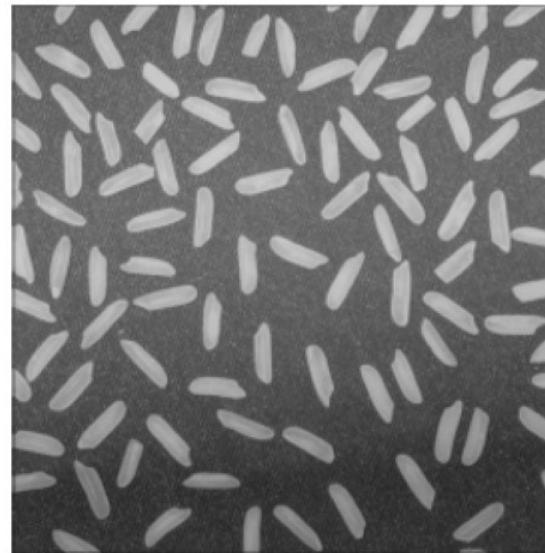
Gray-Scale Morphology

- Application: Smoothing using openings and closings

```
>> f = imread('dowels.tif');
>> fasf = f;
>> for k = 2:5
    se = strel('disk', k);
    fasf = imclose(imopen(fASF, se), se);
end
>> figure, imshow(fASF);
```

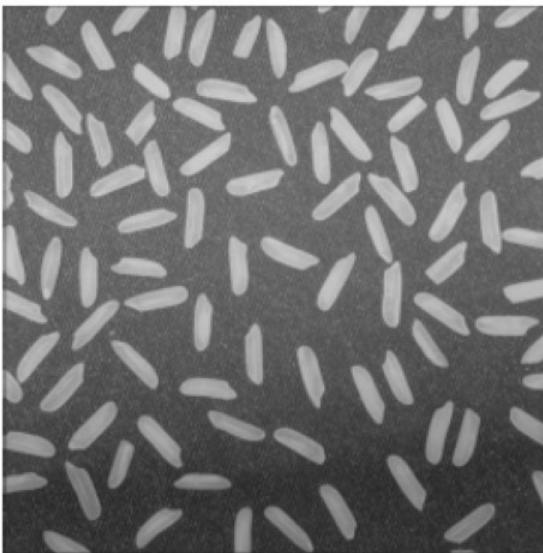
Gray-Scale Morphology

- **Application:** To resolve nonuniform background



Gray-Scale Morphology

- **Application:** To resolve non-uniform background



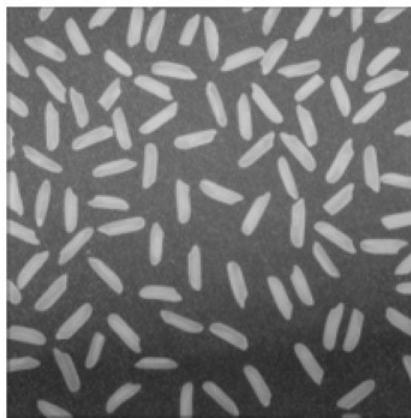
Original image



Threshed image

Gray-Scale Morphology

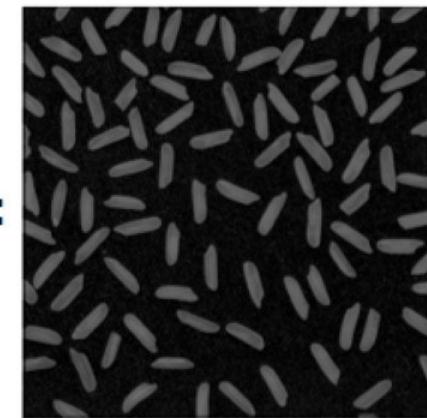
- **Application:** To resolve non-uniform background



Original image



Opened image

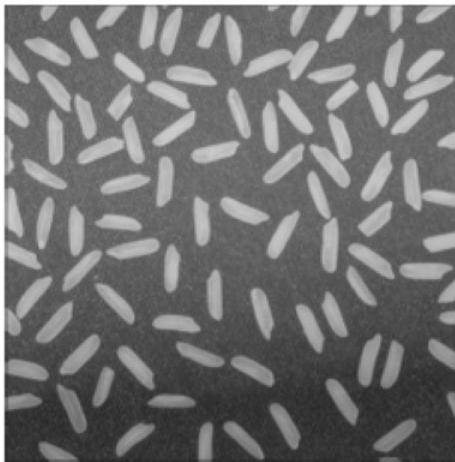


Top-hat image

Subtracting an opened image from the original is called “*top-hat* transformation.”

Gray-Scale Morphology

- **Application:** To resolve non-uniform background



Original image

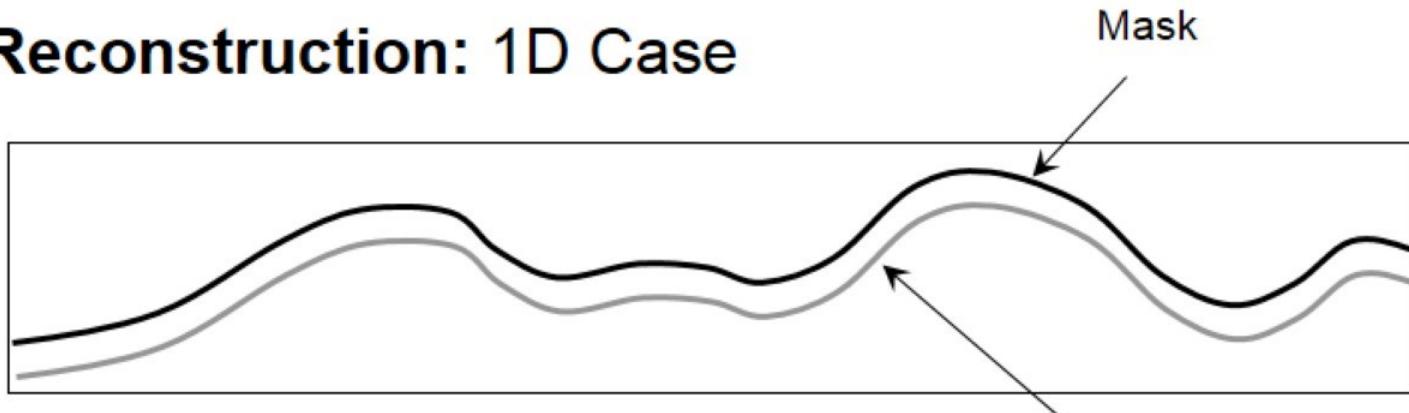


Top-hat image

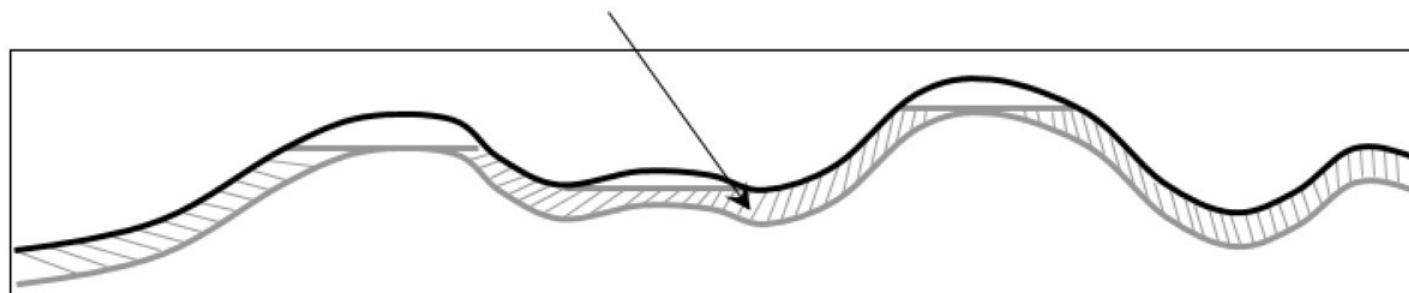
ex_tophat.m

Gray-Scale Morphology

Reconstruction: 1D Case



Iterative computation of
the reconstruction

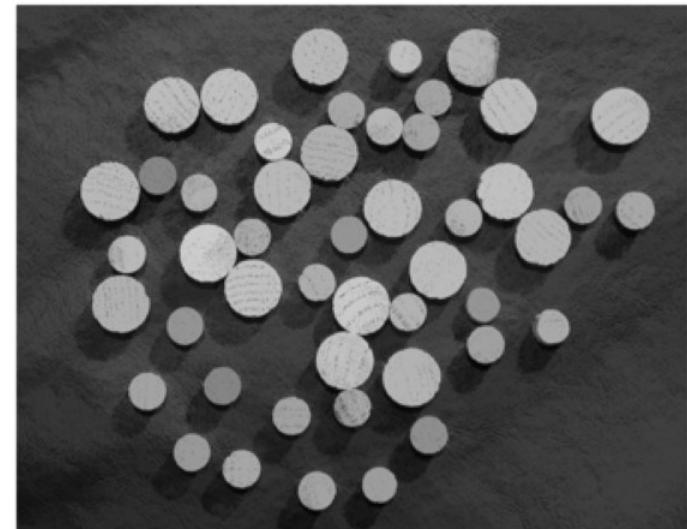


Gray-Scale Morphology

Reconstruction: Opening-by-reconstruction



Original image



Opening-by-reconstruction

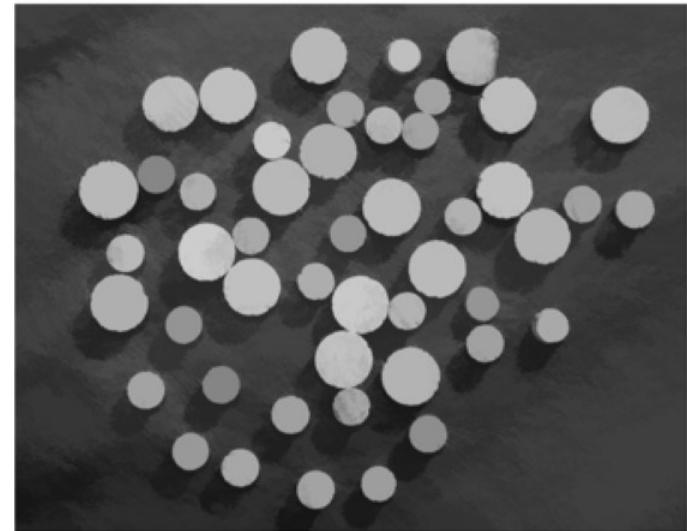
Gray-Scale Morphology

Reconstruction: Opening-by-reconstruction



Original image

gray_recon_op.m



Opening-by-reconstruction
followed by closing-by-
reconstruction



The end of
part II



Image Processing

Morphological Image Processing (Part II)

Pattern Recognition and Image Processing Laboratory (Since 2012)

Gray-Scale Morphology

Application: To isolate the text out of the image of calculator keys



Original Image

Gray-Scale Morphology

Application: To isolate the text out of the image of calculator keys



Opening-by-reconstruction Image

1. Suppress the horizontal reflection along the top of each key.

```
>> f = imread('calculator.tif');
>> f_obb = imreconstruct( ...
>> imerode(f, ones(1, 71)), f);
```

Gray-Scale Morphology

Application: To isolate the text out of the image of calculator keys



2. Perform tophat transformation.

```
>> f_thr = imtophat(f, f_obb);
```

Tophat-by-reconstruction image

Gray-Scale Morphology

Application: To isolate the text out of the image of calculator keys



Opening-by-reconstruction of
Tophat-by-reconstruction image

3. Suppress the vertical reflections on the right edges of the keys.

```
>> g_oir = imreconstruct(imerode ...  
>> (f_thr, ones(1, 11), f_thr);
```

Gray-Scale Morphology

Application: To isolate the text out of the image of calculator keys



Final reconstruction image

4. Perform a dilation and follow by a final reconstruction.

```
>> g_obrd = imdilate(g_obb, ...  
>> ones(1, 21));  
>> f2 = imreconstruction( ...  
>> min(g_obrd, f_thr), f_thr);
```

```
%%ex_tophat.m
%%-----

clear all
close all

f = imread('Fig0926(a) (rice).tif');
se = strel('disk', 10);
fo = imopen(f, se);
f2 = imsubtract(f, fo);
f22 = imtophat(f, se);

level = graythresh(f);
BW = im2bw(f, level);

th = graythresh(f2);
BW_rice = im2bw(f2, th);

figure(1); imshow(f);
figure(2); imshow(fo);
figure(3); imshow(f2);
figure(4); imshow(f22);
figure(5); imshow(BW);
figure(6); imshow(BW_rice);
```

```
% gray_recon_op.m
%
close all

f = imread('dowels.tif');
se = strel('disk', 5);

% ----- Opening by reconstruction -----
fe = imerode(f, se); % Generate a marker, fe.
fobr = imreconstruct(fe, f); % f is a mark.

% ----- Closing by reconstruction -----
fobrc = imcomplement(fobr);
fobrce = imerode(fobrc, se);
fobrcer = imcomplement(imreconstruct(fobrce, fobrc));

figure, imshow(f);
figure, imshow(fe);
figure, imshow(fobr);
figure, imshow(fobrcer);
```