Getting Started With Images, Video, and Matlab

CSE 6367 – Computer Vision
Vassilis Athitsos
University of Texas at Arlington

What Is An Image?

- Grayscale image:
  - A 2D array of intensity values.
    - rows x columns.
  - Typically, 8 bits per intensity value
    - Range from 0 to 255.
- Color image:
  - Three 2D arrays of intensity values.
    - Red, green, blue.

Reading Images in Matlab

```
>> hand_image = imread('data/hands/frame2.bmp', 'bmp');
>> hand_image(53,122,1)   % Red value for row=53, col=122
ans =
   64
>> hand_image(53,122,2)   % Green value for row=53, col=122
ans =
   83
>> hand_image(53,122,3)   % Blue value for row=53, col=122
ans =
   89
```

Displaying Images

- For color images of type uint8, size rows x cols x 3:

```
>> imshow(hand_image);
```

- For color images of type double:
  - values must be between 0 and 1.

```
>> imshow(hand_image);
```

- For grayscale images with values in range [0 255]

```
>> imshow(gray_hand, [0 255]);
```

- For grayscale images with values in range [low high]

```
>> imshow(gray_hand, [low high]);
>> imshow(gray_hand, []);
```

Accessing Matrix Entries

- Size of a matrix:

```
>> size(gray_hand);
>> size(hand_image);
```

- Accessing a submatrix:
  - rows 53 to 57, columns 122 to 125, red color band.

```
>> hand_image(53:57, 122:125, 1);
```

- Modifying an image:
  - row 132, columns 43 to 89, make color yellow ([255,255,0]).

```
>> result_image(132, 43:89, 1) = 255;
>> result_image(132, 43:89, 2) = 255;
>> result_image(132, 43:89, 3) = 0;
```

Useful Things in Matlab

```
>> addpath('c:/users/athitsos/matlab_code’);
>> type read_gray
>> help imwrite
>> who
>> which read_gray
>> clear
```

A Simple Computer Vision Example

- Consider the “walkstraight” sequence.
    - Copyright: Hedvig Kjellström.
  - Static background.
  - Only moving person is a walking human.
- How can we find where the human is in frame 62?
  - By finding where the motion occurs.

frame 61

frame 62

frame 63

Identifying Where Motion Occurred

- Step 1: compute *frame differences* with previous and next frame:
  - diff1 = abs(frame61 – frame62).
  - diff2 = abs(frame63 – frame62).

frame 61

frame 62

frame 63

diff1

diff2

Identifying Where Motion Occurred

- Step 2: select, for each pixel, the smallest value from diff1 and diff2.
  - motion = min(diff1, diff2)
  - Note: diff1 tells us as much about frame 62 as about frame 61.
  - Same with diff2, and frames 62, 63.

motion

frame 61

frame 62

frame 63

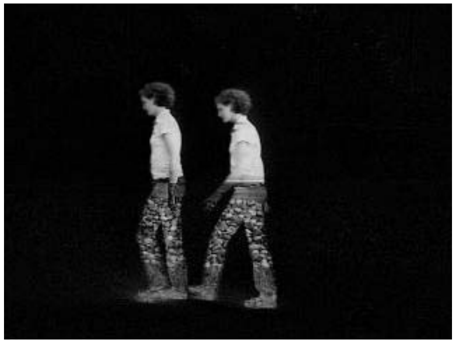
Looking Further in Time

- Instead of comparing with frames 61 and 63, compare with frames 47 and 77:
  - diff1b = abs(frame47-frame62);
  - diff2b = abs(frame77-frame62);
  - motionb = min(diff1b, diff2b);

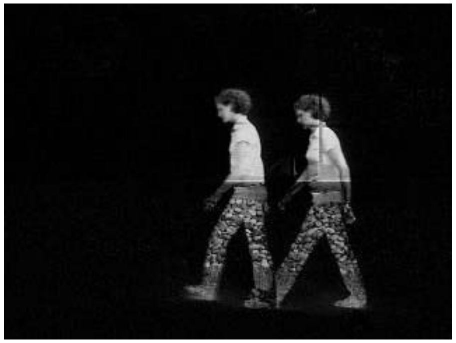
frame 61

frame 62

diff1b



diff2b



motionb

frame 63

Computing the Position

- How can we represent the position?

frame 62

motionb

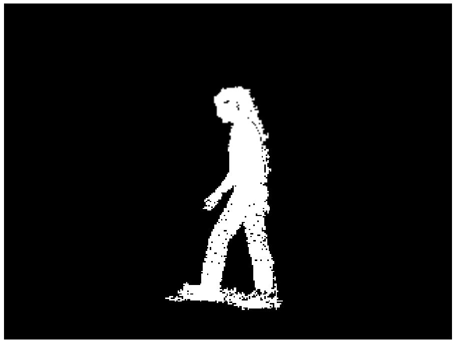
Computing the Position

- How can we represent the position?
  - – Answer 1: a set of pixels.
- A set of pixels is one of many different ways to *represent shape*.
- How do we get from the motion image to shape?

frame 62

motionb

shape

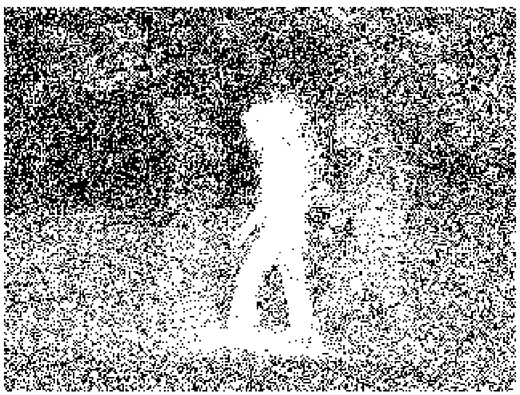


From Motion to Shape

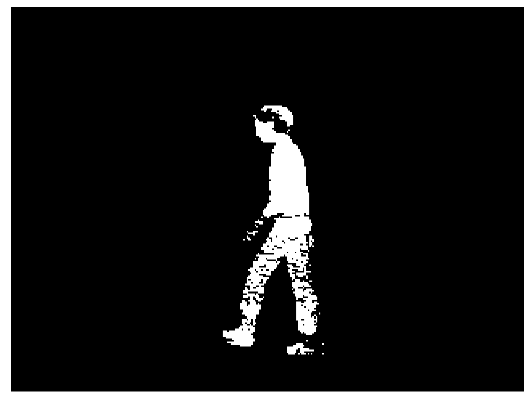
- Step 1: thresholding.

```
threshold = 10;
thresholded = (motion2 > threshold);
imshow(thresholded, []);
```

Thr = 1

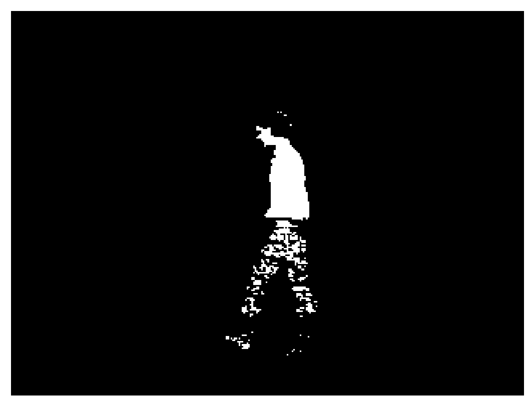


Thr = 50



Thr = 10

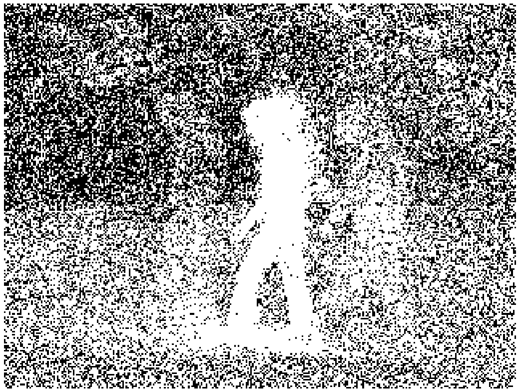
Thr = 100



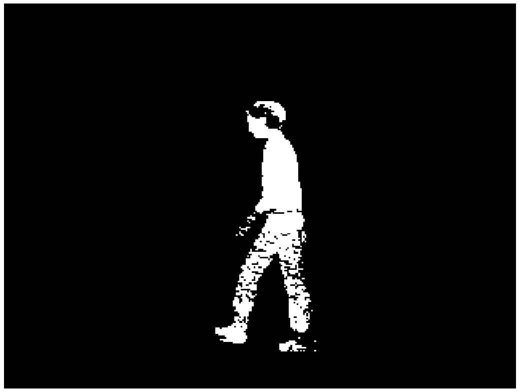
From Motion to Shape

- Problem: we must pick threshold.
  - Picking parameters manually makes methods fragile.

Thr = 1

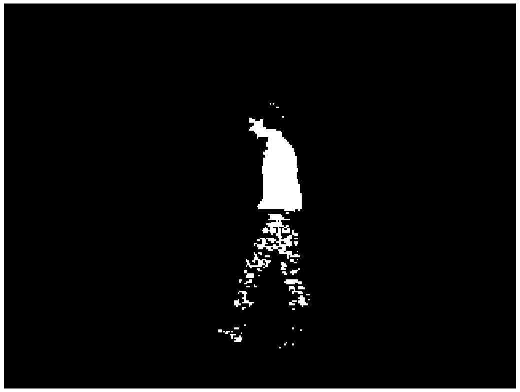


Thr = 50



Thr = 10

Thr = 100



From Motion to Shape

- Choosing a threshold manually:
  - OK for toy example.
  - bad practice oftentimes.
  - sometimes, unavoidable or extremely convenient.
- For our example: thr = 10.
- Problem: lots of small motion areas.
  - What causes them?

Thr = 10

From Motion to Shape

- We should identify the biggest “area”.
  – Connected Component Analysis.
- What is a connected component?

Thr = 10

From Motion to Shape

- We should identify the biggest “area”.
  – Connected Component Analysis.
- What is a connected component?
  – Set of pixels such that you can find a white-pixel path from any of them to any of them.

Thr = 10

From Motion to Shape

- We should identify the biggest “area”.
  – Connected Component Analysis.
- What is a connected component?
  – Set of pixels such that you can find a white-pixel path from any of them to any of them.
    - 4-connected, 8-connected.

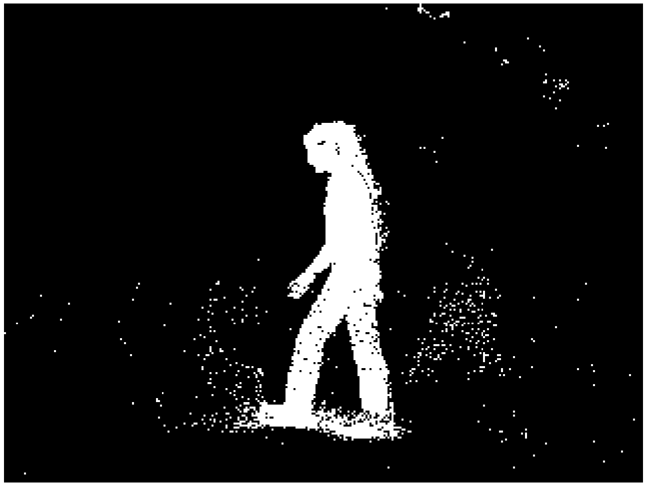
Thr = 10

Connected Components in Matlab

```
[labels, number] = bwlabel(thresholded, 4);
figure(1); imshow(labels, []);
colored = label2rgb(labels, @spring, 'c', 'shuffle');
figure(2); imshow(colored);
```

- bwlabel second argument: 4 or 8-connected.
- label2rgb: assigns random colors, to make it easy to visualize.

Thr = 10



colored

Identifying the Largest Component

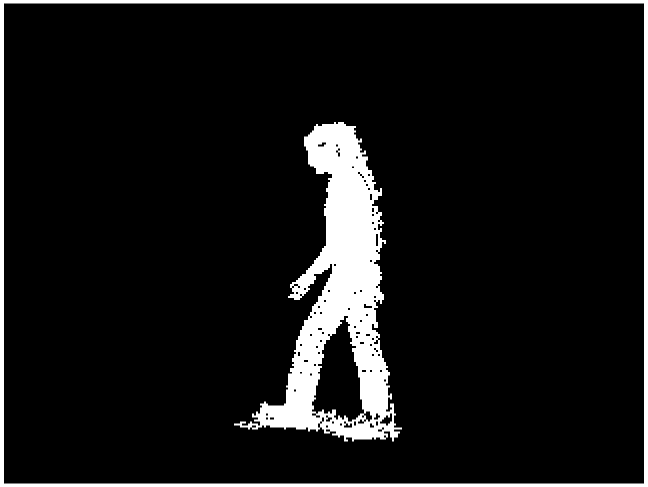
```
[labels, number] = bwlabel(thresholded, 4);
```

- `labels` is an image of connected component IDs.
  - 0 is the ID of the background, which we ignore.
- `number` is the number of connected components.
- We can count the pixels of each component.

```
counters = zeros(1,number);
for i = 1:number
    % first, find all pixels having that label.
    component_image = (labels == i);
    % second, sum up all white pixels in component_image
    counters(i) = sum(component_image(:));
end

[area, id] = max(counters);
person = (labels == id);
```

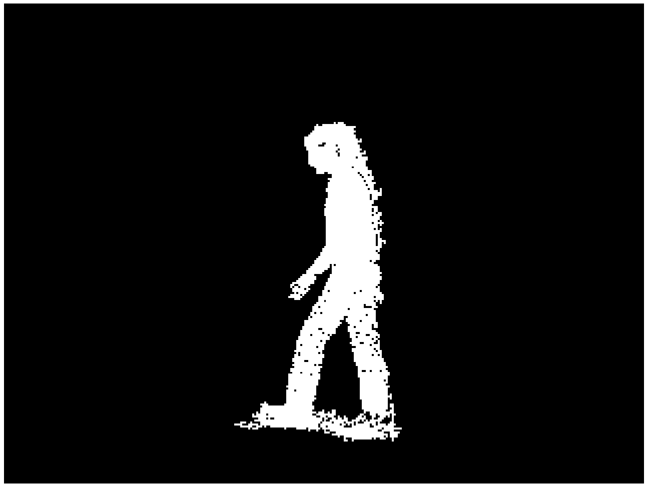
Result

shape



Saving an Image to a File

shape



```
imwrite(uint8(diff1), 'diff1.jpg');
imwrite(uint8(diff1), 'diff2.jpg');
imwrite(uint8(diff1), 'motion2.jpg');
```

- Make sure values are from 0 to 255, otherwise
  - scaling may be needed.
- Make sure you cast to uint8 (8-bit unsigned int).
  - Otherwise the image you save will not look as you expect.

Image Range Outside [0 255]

```
my_image = [
    -2 -2 -2 -2 -2 -2 -2 -2 -2
    -2 -2 -2 -2 -2 -2 -2 -2 -2
    -2 -2 -2 -2 -2 -2 -2 -2 -2
    5 5 5 5 5 5 5 5 5
    -2 -2 -2 -2 -2 -2 -2 -2 -2
    -2 -2 -2 -2 -2 -2 -2 -2 -2
    -2 -2 -2 -2 -2 -2 -2 -2 -2
    -2 -2 -2 -2 -2 -2 -2 -2 -2];

my_image = imresize(my_image, 20);

figure(1); imshow(my_image, []);
```

Pitfalls of Saving an Image

```
% this will not work (produces warning, and black image)
imwrite(my_image, 'trash/my_image.gif');
my_image2 = imread('trash/my_image.gif');
figure(2); imshow(my_image2, []);
```

my_image

my_image2

Normalizing the Image Range

- How do we convert an image so that its range is between 0 and 255?

Normalizing the Image Range

- How do we convert an image so that its range is between 0 and 255?

```
% converting to [0 255] range:
low = min(my_image(:));
high = max(my_image(:));
range = high - low;

% this will give warning
converted = (my_image - low) * 255 / range;

% this will also give warning.
imwrite(converted, 'trash/my_image2.gif');
my_image2 = imread('trash/my_image2.gif');
figure(2); imshow(my_image2, []);
```

```matlab
function result = normalize_range(input_image, target_low, target_high)

% function result = normalize_range(input_image, target_low,  target_high)
%
% shift the values in input_image so that the minimum value is
% target_low and the maximum value is target_high.
%
% function result = normalize_range(input_image)
%
% returns normalize_range(input_image, 0, 255)


if nargin == 1
    target_low = 0;
    target_high = 255;
end

target_range = target_high - target_low;
low = min(input_image(:));
high = max(input_image(:));
range = high - low;

result = (input_image - low) * target_range / range + target_low;
```

```matlab
function save_normalized(input_image, filename)

% function result = save_normalized(input_image, filename)
%
% normalize the values in input_image so that the minimum value is
% 0 and the maximum value is 255, and save the normalized image
% to the specified filename.

normalized = normalize_range(input_image);
imwrite(uint8(normalized), filename);
```

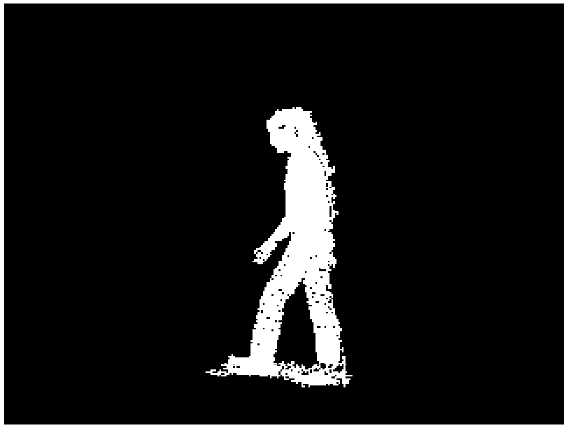
Image Formats

- Why are we saving as JPG?
- What about other formats (GIF, BMP, TIFF)?

Image Formats

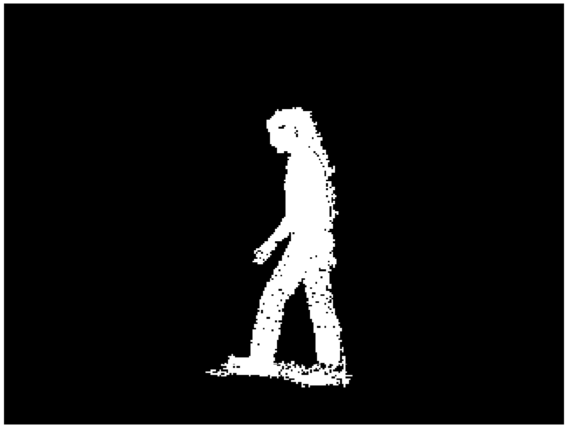
- Why are we saving as JPEG?
- What about other formats (GIF, BMP, TIFF)?
- JPEG: good for photographs
  - lossy compression.
- GIF: good for images with single-color regions, few colors.
  - Possibly lossy, only supports 256 image colors.
- TIFF, BMP: larger files, no loss of information.

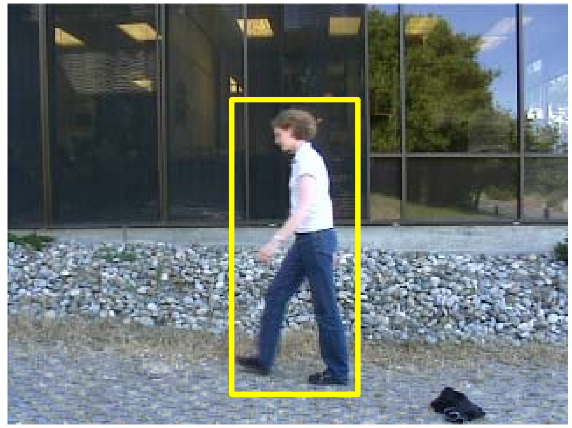
Shape Representations



- How about other representations of shape, in addition to connected components?

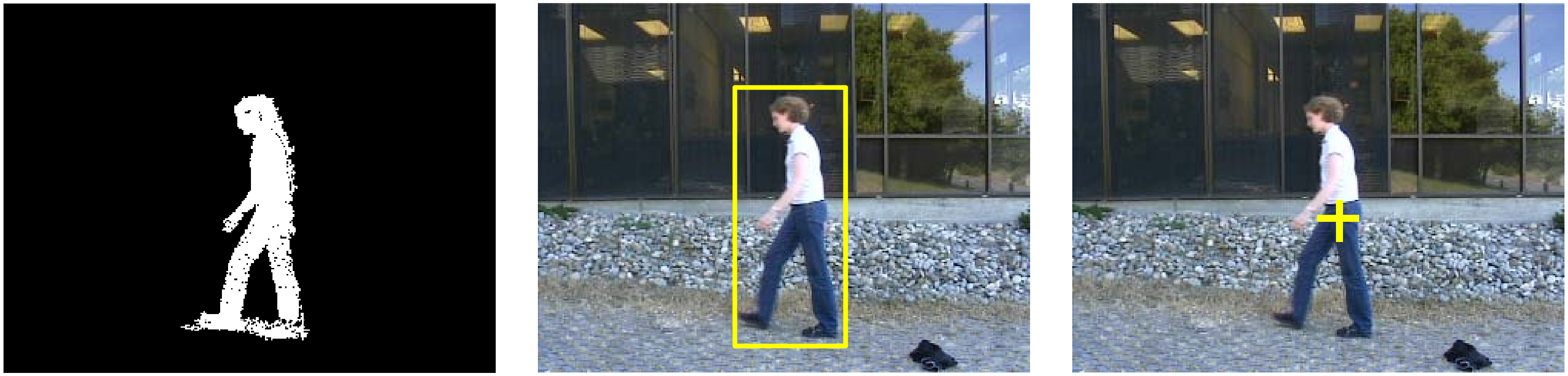
Shape Representations





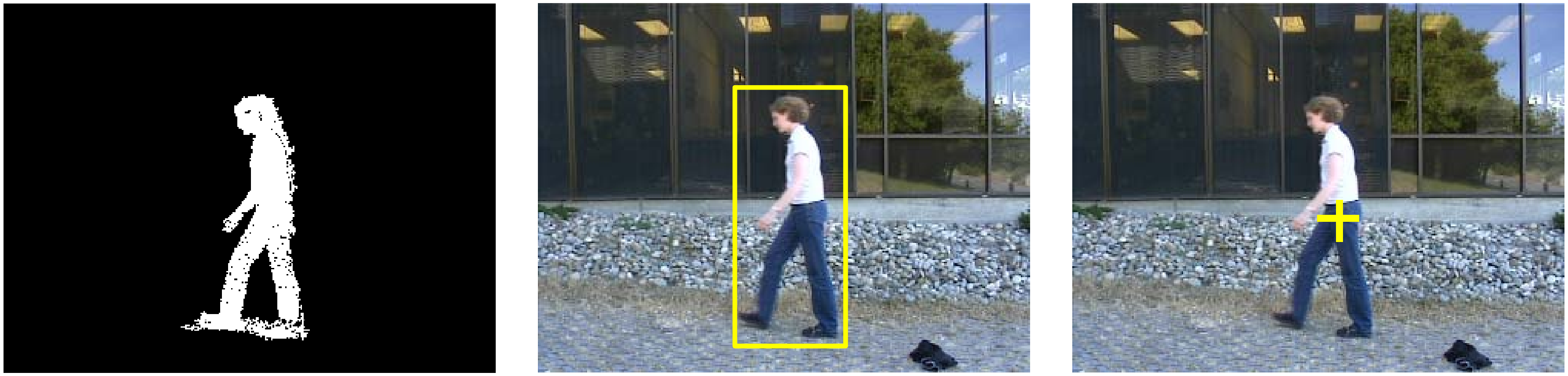
- Bounding box:
  - topmost, bottom-most, leftmost, rightmost locations of shape pixels.

Shape Representations



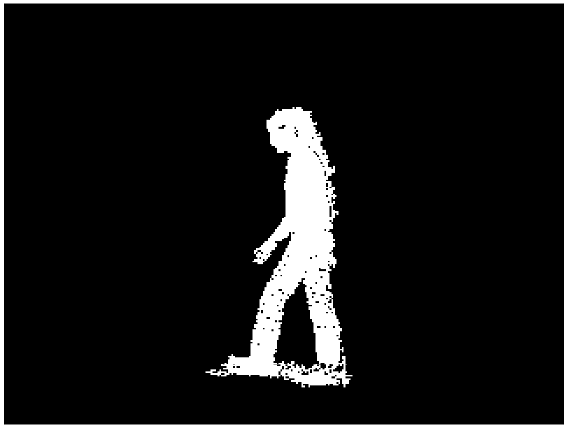
- Bounding box:
  - topmost, bottom-most, leftmost, rightmost locations of shape pixels.
- Centroid:

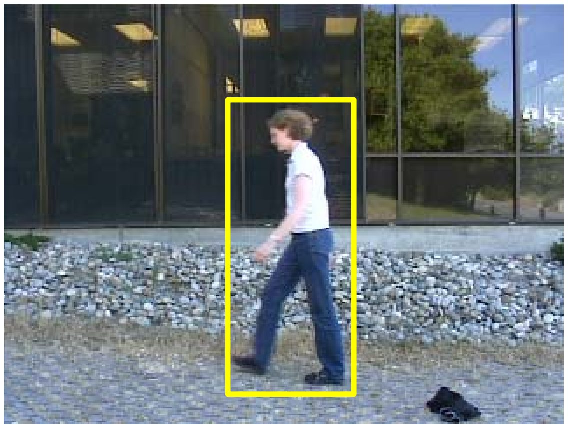
Shape Representations



- Bounding box:
  - topmost, bottom-most, leftmost, rightmost locations of shape pixels.
- Centroid:
  - Center of bounding box.

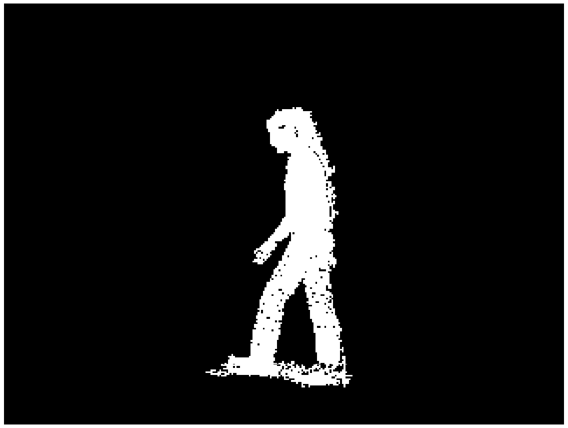
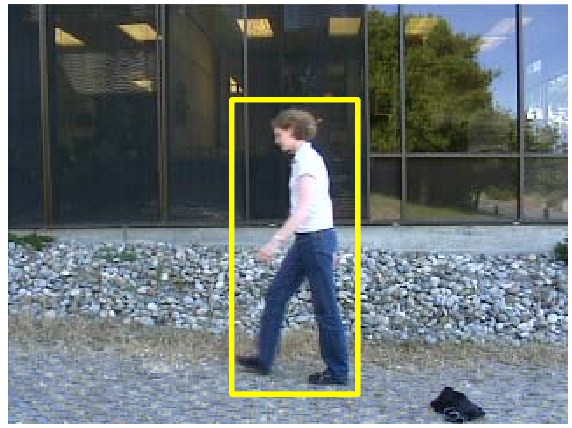
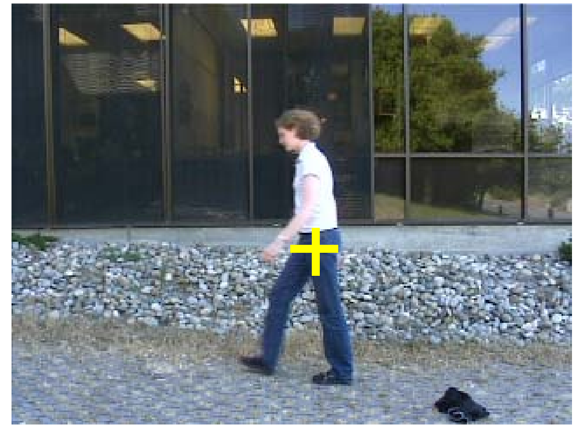
Shape Representations





- Bounding box:
  - topmost, bottom-most, leftmost, rightmost locations of shape pixels.
- Centroid:
  - Center of bounding box.
  - Center of the connected component.

Shape Representations

- Bounding box:
  - topmost, bottom-most, leftmost, rightmost locations of shape pixels.
- Centroid:
  - Center of bounding box.
  - Center of the connected component.
    - How can we compute that?

Center of Connected Component

```
[rows, cols] = size(person);
sum_i = 0;
sum_j = 0;
counter = 0;

for i = 1:rows;
    for j = 1:cols
        if person(i,j) ~= 0
            sum_i = sum_i + i;
            sum_j = sum_j + j;
            counter = counter + 1;
        end
    end
end

center_i = sum_i / counter;
center_j = sum_j / counter;
```

Computing the Center - Shorter

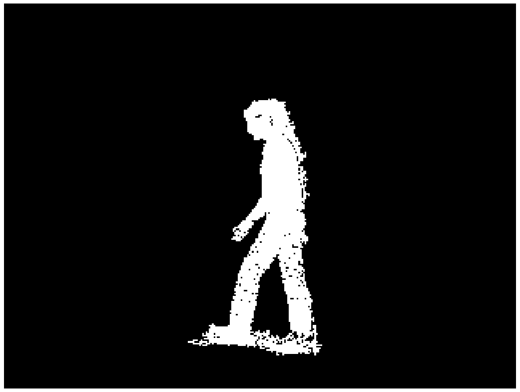
```
% find coordinates of all non-zero pixels.
[rows cols] = find(person);
center_i = mean(rows);
center_j = mean(cols);
```

Visualizing the Result

```
result_image = original_image; % make a copy

center_row = round(center_i);
center_col = round(center_j);

left = max(center_col - 5, 1);
right = min(center_col + 5, cols);
bottom = min(center_row + 5, cols);
top = max(center_row - 5, 1);

% draw horizontal line of cross
result_image(center_row, left:right, 1) = 255;
result_image(center_row, left:right, 2) = 255;
result_image(center_row, left:right, 3) = 255;

% draw vertical line of cross, use shortcut since all
   values are 255
result_image(top:bottom, center_col, :) = 255;
imshow(result_image / 255);
```

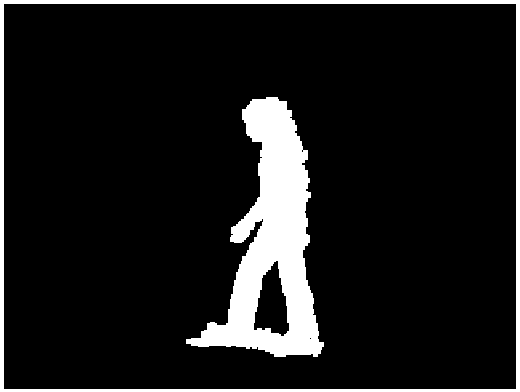
Morphology: Dilation

person

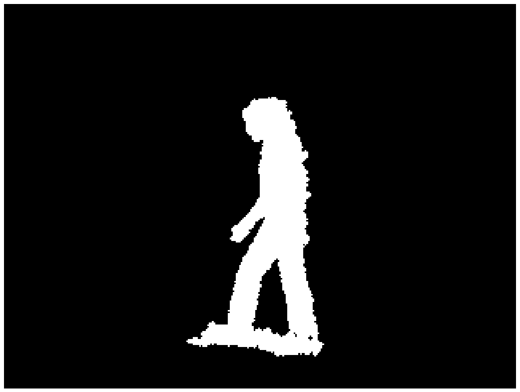


- For every white pixel in original image:
  - Make all neighbors white in result.
- What is a neighbor?
  - Specified as an extra parameter.

```
% 8-connected neighbors
imdilate(person, ones(3,3))
```



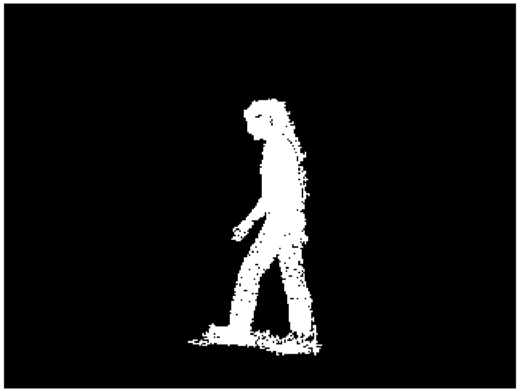
```
% 4-connected neighbors
neighborhood = [0,1,0; 1,1,1; 0,1,0])
imdilate(person, neighborhood)
```



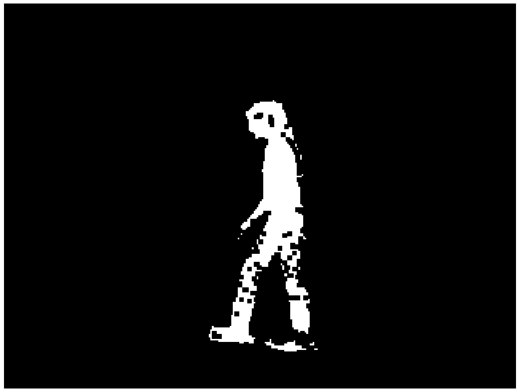
Morphology: Erosion

- For every black pixel in original image:
  - Make all neighbors black in result.
- Neighborhood: 2nd argument.

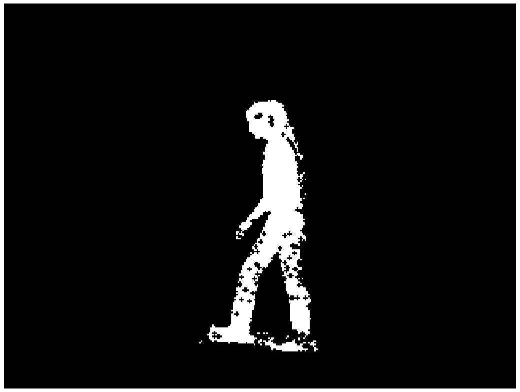
```
person
```



```
% 8-connected neighbors
imerode(person, ones(3,3))
```



```
% 4-connected neighbors
neighborhood = [0,1,0; 1,1,1; 0,1,0])
imerode(person, neighborhood)
```



Note on Erosion and Dilation

- Are erosion and dilation mathematical inverses of each other?
  - If we erode and then dilate, do we get the original image?

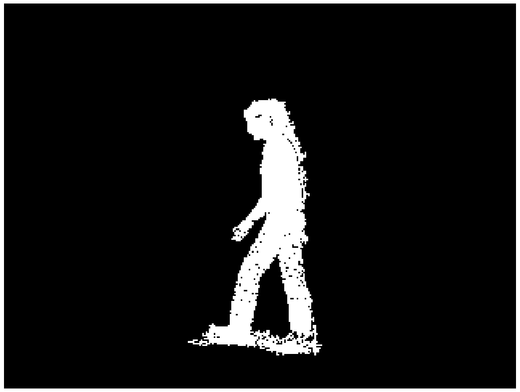
Note on Erosion and Dilation

- Erosion and dilation are *not* mathematical inverses of each other.
  - If they were, opening and closing would not change the image.

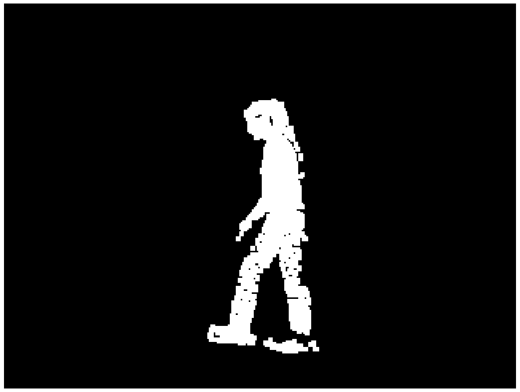
Morphology: Opening

- First erode, then dilate.
- Opens up holes in the shape.

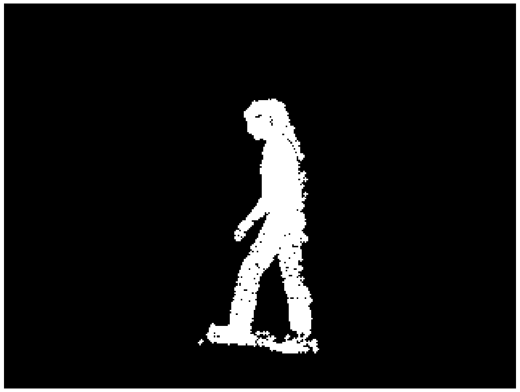
```
person
```



```
% 8-connected neighbors
imopen(person, ones(3,3))
```



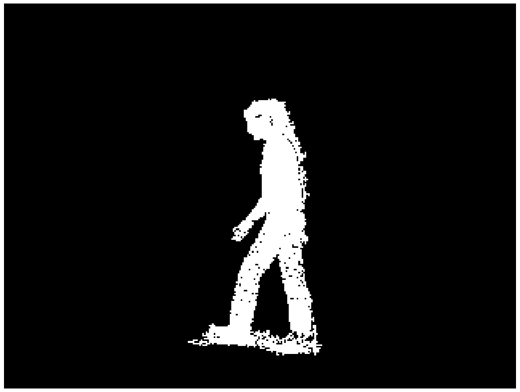
```
% 4-connected neighbors
neighborhood = [0,1,0; 1,1,1; 0,1,0])
imopen(person, neighborhood)
```



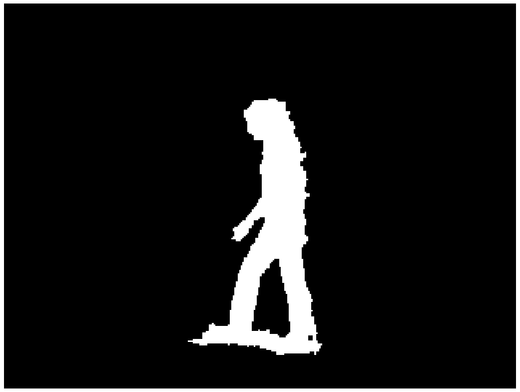
Morphology: Closing

- First dilate, then erode.
- Shrinks or eliminates holes in the shape.

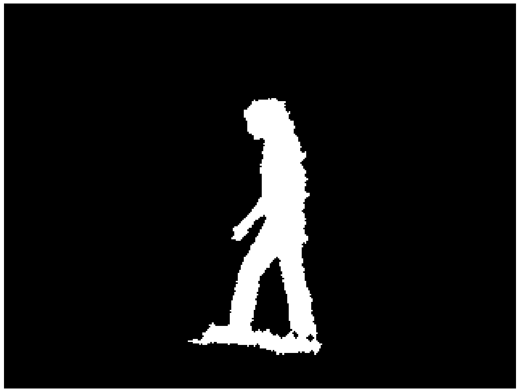
person



```
% 8-connected neighbors
imclose(person, ones(3,3))
```



```
% 4-connected neighbors
neighborhood = [0,1,0; 1,1,1; 0,1,0])
imclose(person, neighborhood)
```



Notes on mean, min, max, sum

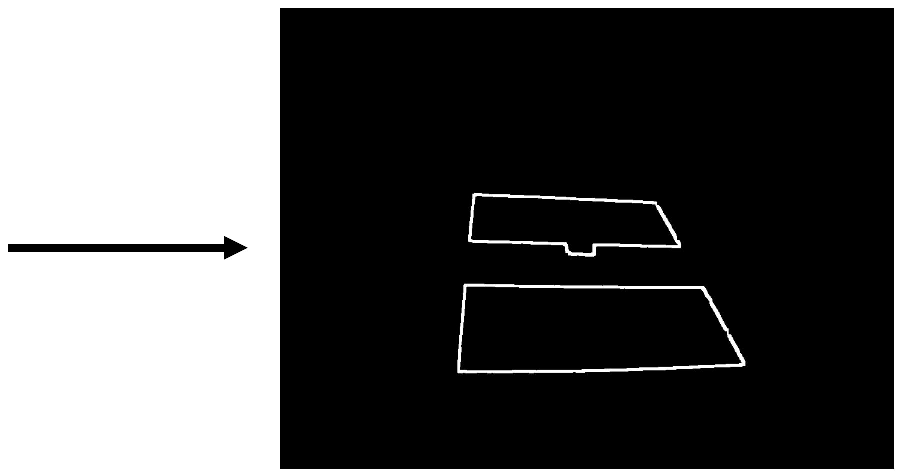
- These functions return the minimum of each column.
- To apply them to entire matrix, there are two ways:

```
min_value = min(min(my_matrix));
min_value = min(my_matrix(:));
```

- my_matrix(:) converts the whole matrix into a single-column vector.

Information from Color

- Color can provide useful information about object location and shape.
  - Morphological operations can help refine that information.
- A simple example: finding boundaries of a tennis court.



Tennis Boundaries

- Extract each of the three color bands.

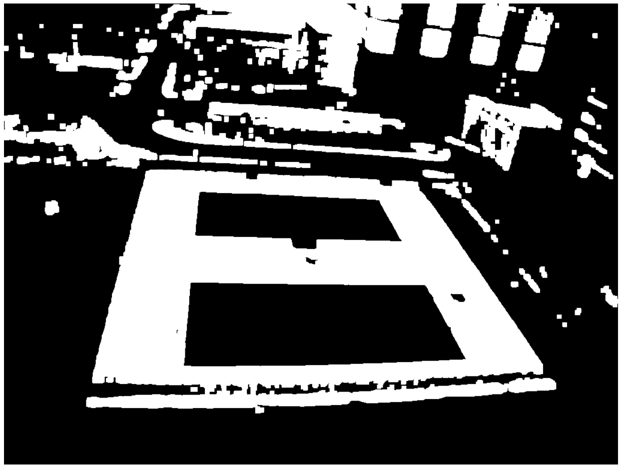
```
filename = 'data/tennis_court2.jpg';
color = double(imread(filename));
r = color(:,:, 1);
g = color(:,:, 2);
b = color(:,:, 3);
```

- Identify red areas:

```
red = ((r - g > 10) & (r - b > 10));
red = imdilate(red, ones(7,7));
```

- Identify green areas:

red



Tennis Boundaries

- Extract each of the three color bands.

```
filename = 'data/tennis_court2.jpg';
color = double(imread(filename));
r = color(:,:, 1);
g = color(:,:, 2);
b = color(:,:, 3);
```

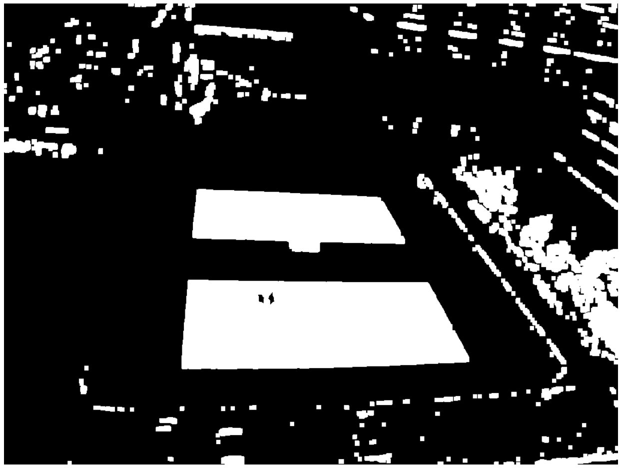
- Identify red areas:

```
red = ((r - g > 10) & (r - b > 10));
red = imdilate(red, ones(7,7));
```

- Identify green areas:

```
green = ((g - r > 10) & (g - b > 0));
green = imdilate(green, ones(7,7));
```

green

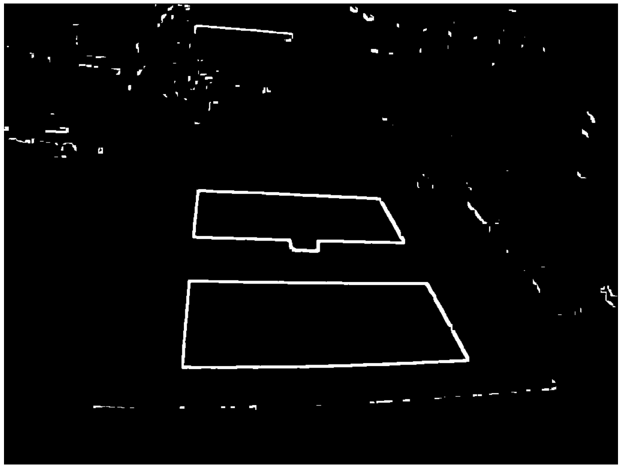


Tennis Boundaries

- Find boundary between red and green areas.
  - Note: red and green were dilated (see Matlab code on previous slide), so that their boundary is part of both the red and the green area.

```
boundary = (red & green);
```

green



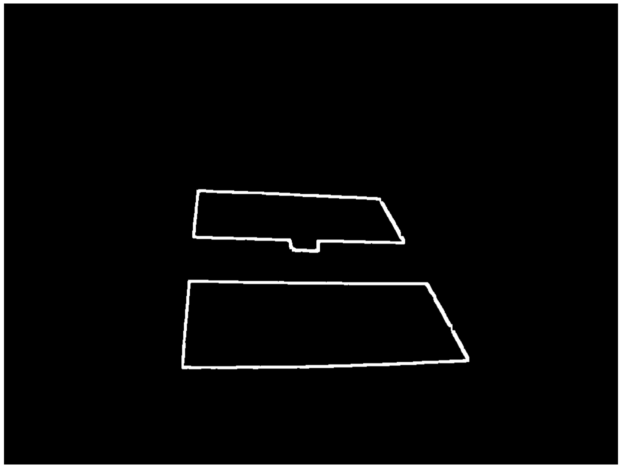
  - We note that the boundaries of the two courts are the two largest connected components.

Extracting the Boundaries

- Extract the first and second largest connected component of the boundary image.
  - See code/get_component.m

```
b1 = get_component(boundary, 1);
b2 = get_component(boundary, 2);
figure(1); imshow(b1 | b2);
```

final result

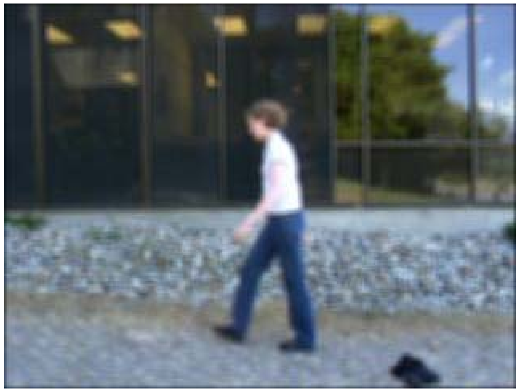


Blurring

- Intuitively: replacing each pixel value with a weighted average of values in its neighborhood.
  - Simplest: N x N neighborhood, all weights equal.

```
original = double(imread('walkstraight/frame0062.tif'));
kernel = ones(5,5) / 25;
blurred = imfilter(original, kernel);
```

original



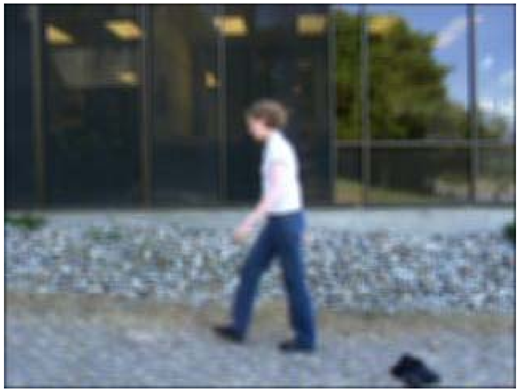
blurred

Blurring

- What happens if we increase the kernel size?

```
original = double(imread('walkstraight/frame0062.tif'));
kernel = ones(5,5) / 25;
blurred = imfilter(original, kernel);
```

original



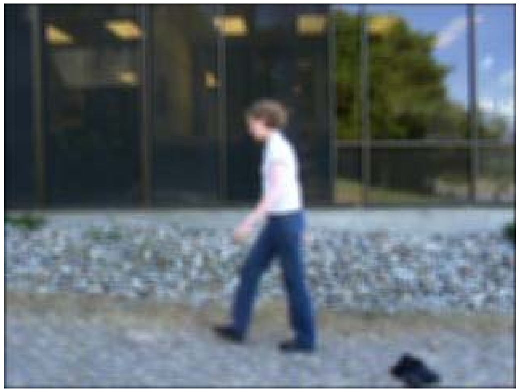
blurred

Blurring

- What happens if we increase the kernel size?
  - More blurring.

```
original = double(imread('walkstraight/frame0062.tif'));
kernel = ones(5,5) / 25;
blurred = imfilter(original, kernel);
```

original



blurred

Blurring with Gaussians

- Blurring kernel has unequal weights.
  – Larger weights closer to the center.
  – Equal weights for equal distance to the center.
- Matlab function: fspecial.
  – Third argument: standard deviation.
  – Second argument: size of kernel.
    - Rule of thumb: odd integer, > 6 * std.

```
kernel = fspecial('gaussian', 6 * ceil(3.0) + 1, 3.0);
blurred3 = imfilter(original, kernel);
kernel = fspecial('gaussian', 6 * ceil(7.0) + 1, 7.0);
blurred7 = imfilter(original, kernel);
```

Blurring with Gaussians

original

blurred3 (std = 3)

blurred7 (std = 7)

Why Blur?

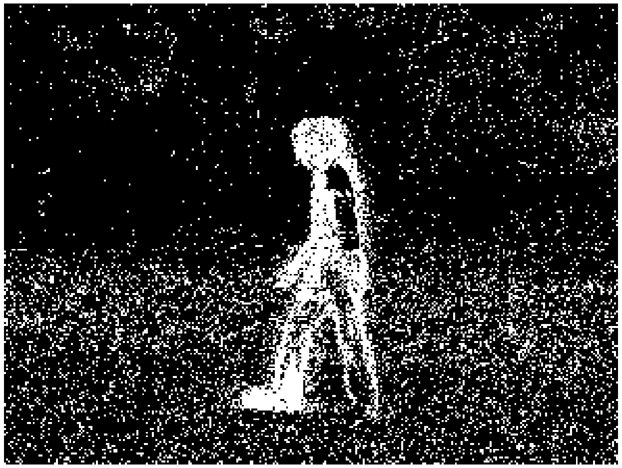
- Can remove a lot of noise.
- Throws away details we want to ignore.
- Emphasizes larger-scale structures.
- Creates smoother images.
  - Useful for some optimization methods, such as gradient descent, that we will study later.

Frame Differencing with Blurring

```
frame61 = read_gray('walkstraight/frame0061.tif');
frame62 = read_gray('walkstraight/frame0062.tif');
frame63 = read_gray('walkstraight/frame0063.tif');


% without blurring
diff1 = abs(frame62 - frame61);
diff2 = abs(frame62 - frame63);
motion = min(diff1, diff2);


% with blurring
kernel = fspecial('gaussian', 9, 1.4);

blurred_frame61 = imfilter(double(frame61), kernel);
blurred_frame62 = imfilter(double(frame62), kernel);
blurred_frame63 = imfilter(double(frame63), kernel);

diff1b = abs(blurred_frame62 - blurred_frame61);
diff2b = abs(blurred_frame62 - blurred_frame63);
motion2b = min(diff1b, diff2b);
```

Results

original



motion > 3
(no blurring)

motion2 > 3
(blurring, std = 1.4)

Linear Filtering

- Linear filtering is the exact same operation as convolution with a kernel/filter.
- If:
  - kernel has 2M+1 rows, 2N+1 cols.
  - input is the original image, of U rows and V cols.
  - result is the output of convolution.
- Then convolution can be coded as:

```
result = zeros(U, V);
for i = (M+1):(U-M)
    for j = (N+1):(V-N)
        result(i,j) = sum(sum(kernel .* input((i-M):(i+M), (j-N):(j+N))));
    end
end
```

Intuition on Linear Filtering

```
result = zeros(U, V);
for i = (M+1):(U-M)
    for j = (N+1):(V-N)
        result(i,j) = sum(sum(kernel .* input((i-M):(i+M), (j-N):(j+N))));
    end
end
```

- result(i,j) is a weighted average of the neighborhood of input(i,j).
  - size of neighborhood defined by kernel.
  - weights for weighted average also defined by kernel.
- Note: by using different kernels, lots of interesting operations can be defined.
  - E.g., see dx and dy filters later in these slides.

Nonlinear vs. Linear Filters

- Linear filters are convolutions with a kernel.
  - In Matlab, use imfilter, or filter2.
- Nonlinear filters are not convolutions.
  - The result value at a pixel is a function of the original values in a neighborhood of that pixel.
  - Each nonlinear filter must be implemented as a separate function.
- Examples of nonlinear filters:
  - Thresholding.
  - Non-maxima suppression (see lecture on edge detection).