Digital Image Fundamentals

Kuliah ke-2

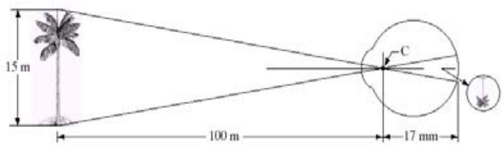
Program Studi S1 Reguler

DTE FTUI Slides©2009

Sistem Visual Manusia

Pembentukan Citra oleh Sensor Mata

- Intensitas cahaya ditangkap oleh diagram iris dan diteruskan ke bagian retina mata.
- Bayangan obyek pada retina mata dibentuk dengan mengikuti konsep sistem optik dimana fokus lensa terletak antara retina dan lensa mata.



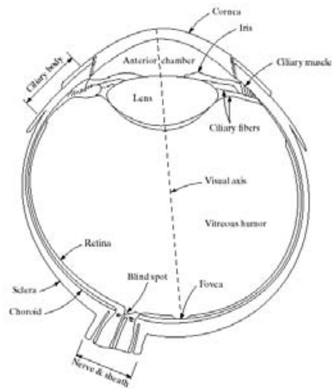


FIGURE 2.1 Simplified diagram of a cross section of the human eye.

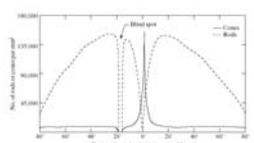
Sistem Visual Manusia

Fovea memiliki dua jenis reseptor

- *Cone receptor*, sensitif terhadap warna, visi cone disebut *photocopic vision* atau *bright light vision*
- *Rod receptor*, memberikan gambar keseluruhan pandangan dan sensitif terhadap iluminasi tingkat rendah, visi *rod* disebut *scotopic vision* atau *dim-light vision*

Blind Spot

- adalah bagian retina yang tidak mengandung receptor
- tidak dapat menerima dan menginterpretasi informasi



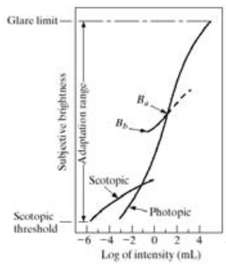
Sistem Visual Manusia

Subjective brightness

- Tingkat kecemerlangan yang dapat ditangkap sistem visual manusia;
- Fungsi logaritmik intensitas cahaya yang masuk ke mata manusia;
- Daerah intensitas bergerak dari ambang *scotopic* (redup) ke ambang *photocopic* (terang).

Brightness adaption

- Fenomena penyesuaian mata manusia dalam membedakan gradasi tingkat kecemerlangan;
- Batas daerah tingkat kecemerlangan yang mampu dibedakan mata manusia lebih kecil dibandingkan daerah tingkat kecemerlangan sebenarnya.

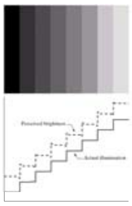


Sistem Visual Manusia

Kepekaan dalam pembedaan tingkat kecemerlangan merupakan fungsi yang tidak sederhana

Dapat dijelaskan dengan fenomena:

- *Mach Band*
- *Simultaneous Contrast*



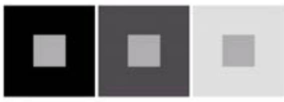


FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Ilusi Optik

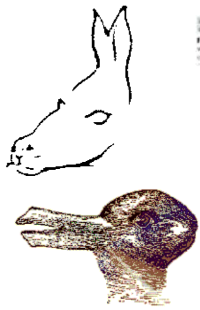
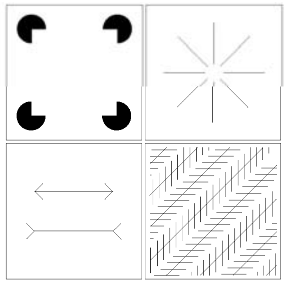


FIGURE 2.9 Some well-known optical illusions.



Spektrum elektro-magnetik

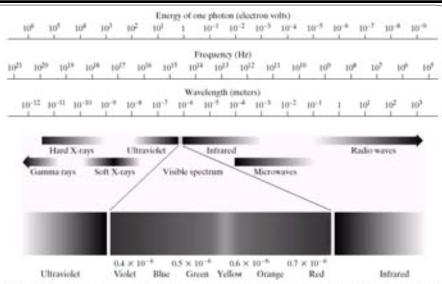
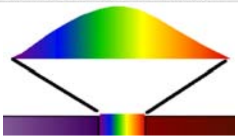
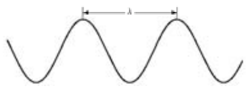


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.



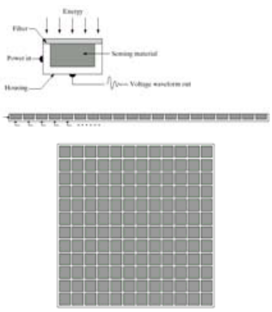
Satu panjang gelombang (λ)

FIGURE 2.11 Graphical representation of one wavelength.



Sensor pencitraan

FIGURE 2.12 (a) Single imaging sensor. (b) Line sensor. (c) Array sensor.



Sensor tunggal + gerak → 2D

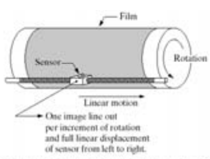
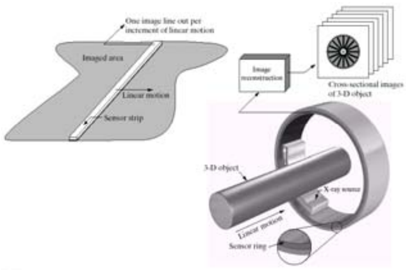


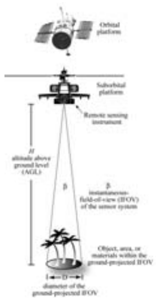
FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

Sensor strip



a b
FIGURE 2.14 (a) Image acquisition using a linear sensor strip. (b) Image acquisition using a circular sensor strip.

Pengertian Sensor Aktif dan Pasif



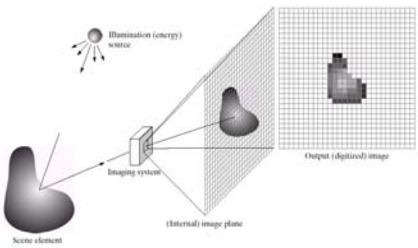
Sensor Pasif

- Sistem sensor yang merekam data obyek tanpa mengirimkan energi
- Sumber energi: sinar matahari, sinar lampu, dsb.
- Contoh: sensor optik dari kamera foto, sensor optik pada sistem *remote sensing*

Sensor Aktif

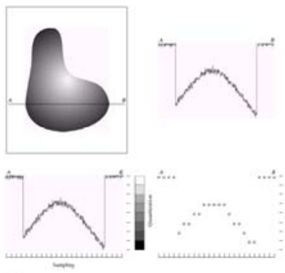
- Sistem sensor yang merekam data obyek dengan mengirimkan dan menerima pantulan energi yang dikirim ke arah obyek
- Energi yang dikirim: gelombang pendek, sinar X, dsb.
- Contoh: sensor Rontgen untuk foto thorax, sensor gelombang pendek pada sistem radar, sensor *ultrasound* pada sistem USG

Contoh Akuisisi Citra

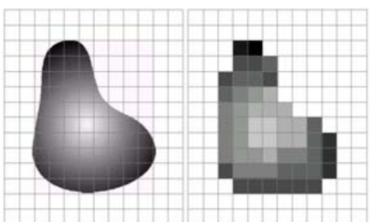


a
b c d e
FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Membuat citra digital



Sampling & Kuantisasi



a b
FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Bit yang diperlukan

TABLE 2.1
Number of storage bits for various values of N and k.

N/k	1 (L = 2)	2 (L = 4)	3 (L = 8)	4 (L = 16)	5 (L = 32)	6 (L = 64)	7 (L = 128)	8 (L = 256)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,360,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

Konvensi koordinat citra digital

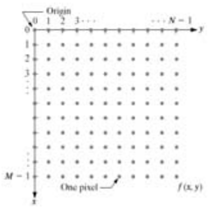


FIGURE 2.18 Coordinate convention used in this book to represent digital images.

Pengertian

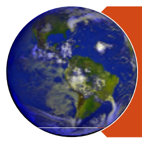
Citra Digital

- Fungsi intensitas cahaya *f(x,y)*
  - harga *x* dan *y* merupakan koordinat spasial
  - harga fungsi *f* pada setiap titik *(x,y)* merupakan tingkat kecemerlangan citra pada titik tersebut
- Digitisasi f(x,y)
  - diskritisasi koordinat spasial (*sampling*)
  - diskritisasi tingkat kecemerlangan/keabuan (kuantisasi)
- Matriks
  - indeks baris dan kolom menyatakan suatu titik pada citra
  - elemen matriks (elemen gambar/piksel/pixel/picture element/pels) menyatakan tingkat keabuan pada titik tersebut

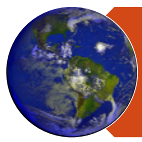
Resolusi Spasial

- Resolusi Citra (resolusi spasial dan resolusi kecemerlangan): berpengaruh pada besarnya informasi citra yang hilang
- Resolusi spasial: halus/kasarnya pembagian kisi-kisi baris dan kolom
- Transformasi citra kontinu ke citra digital disebut digitisasi (sampling)
- Hasil digitisasi dengan jumlah baris 256 dan jumlah kolom 256 – resolusi spasial 256 x 256

Kecemerlangan/Brightness



Resolusi kecemerlangan (intensitas/brightness): halus/kasarnya pembagian tingkat kecemerlangan



Transformasi data analog yang bersifat kontinu ke daerah intensitas diskrit disebut kuantisasi. Bila intensitas piksel berkisar antara 0 dan 255, resolusi kecemerlangan citra adalah 256

Sampling

Sampling Uniform

- mempunyai spasi (interval) baris dan kolom yang sama pada seluruh area sebuah citra

Sampling Non-uniform

- bersifat adaptif tergantung karakteristik citra dan bertujuan untuk menghindari adanya informasi yang hilang

Kuantisasi

Kuantisasi Uniform
- Mempunyai interval pengelompokan tingkat keabuan yang sama
- Misal: intensitas 1 s/d 10 diberi nilai 1, intensitas 11 s/d 20 diberi nilai 2, ...

Kuantisasi Non-uniform
- Kuantisasi yang lebih halus pada bagian citra yang detil/tekstur atau batas suatu wilayah obyek
- Kuantisasi yang lebih kasar pada wilayah yang sama (homogen) pada bagian obyek

Kuantisasi Tapered:
- Kuantisasi secara lebih halus pada tingkat keabuan yang sering muncul
- Di luar batas daerah tersebut dapat dikuantisasi lebih kasar (local stretching).

Subsampling: ukuran berubah, resolusi spasial tetap

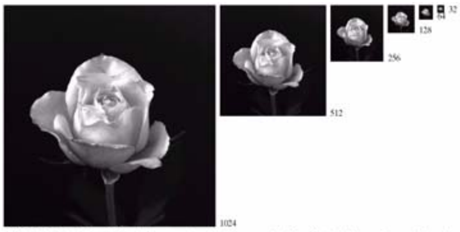
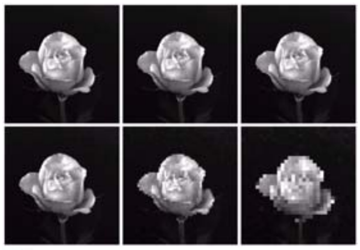


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

25

Resampling: ukuran tetap, resolusi spasial berubah

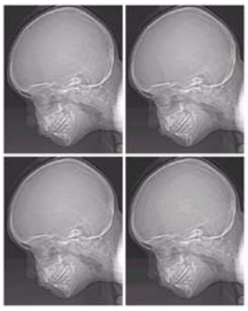


a b c
d e f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

26

Gray level berubah, resolusi tetap



a b
c d

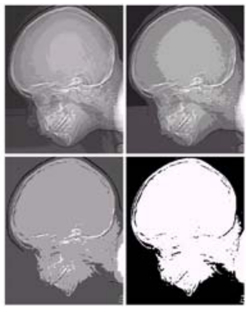
FIGURE 2.21 (a) 452 × 374, 256-level image. (b)–(d) Image displayed in 128, 64, and 32 gray levels, while keeping the spatial resolution constant.

27

Idem hanya gray level makin kecil

e f
g h

FIGURE 2.21 (Continued) (e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)



28

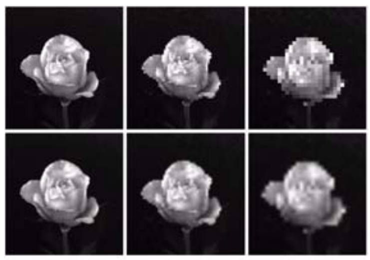
Detil citra: rendah, sedang, tinggi

a b c

FIGURE 2.22 (a) Image with a low level of detail. (b) Image with a medium level of detail. (c) Image with a relatively large amount of detail. (Image (b) courtesy of the Massachusetts Institute of Technology.)

29

Perbesar ke 1024x1024



a b c
d e f

FIGURE 2.25 Top row: images zoomed from 128 × 128, 64 × 64, and 32 × 32 pixels to 1024 × 1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

30

Tampilan Citra dan Persepsi

Tampilan

- CRT, LCD, DLP, Plasma, LCOS, D-ILA
- HDTV, dinding tampilan
- PDA, ponsel, Gameboy
- Stereoskopik (3D)

Persepsi

- Human Vision System (HVS)
- Penyakit terkait sistem pandangan dan perawatan kesehatan

31

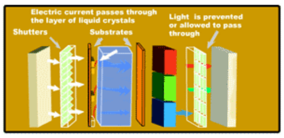
CRT: Cathode Ray Tube

CRT Direct View/Rear Projection Advantages	CRT Direct View/Rear Projection Disadvantages
• Among the brightest and clearest alternatives • Excellent color and contrast potential • Relatively inexpensive • Excellent life expectancy	• Heavy • Very deep • Analogue connectivity or D/A conversion of digital input connections • Potential for screen burn-in

32

LCD: Liquid Crystal Display

Philips 42FD9954 Flat Screen LCD Display



Masa depan: semakin besar, cepat dan murah

LCD Display Advantages	LCD Display Disadvantages
• Good color reproduction • Very thin • Lightweight • Perfect sharpness at native resolution • Excellent longevity • No screen burn-in effect	• Fixed resolution • Notorious "screen door" effect on lesser models • Poor contrast ratios (even excellent units have only 700:1) • Very difficult to produce deep blacks (see above) • Weak and "stuck" pixels are common • Viewing angle on older models may be narrow • Potential for slower refresh rates than plasma (some newer models are getting better)

33

Virtual Wall (Dinding Maya)

NASA Space Shuttle ditayangkan di dinding tampilan

34

Display pada Ponsel

35

3D Display

36

The Ultimate Display: Tampilan Retinal Maya

Video time – Fractals (image formation simulated by Computer)

MATLAB® Time

Konvensi koordinat

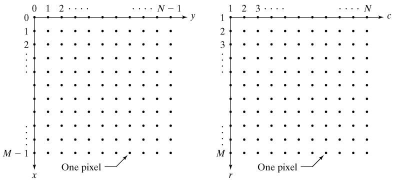


FIGURE 2.1 Coordinate conventions used (a) in many image processing books, and (b) in the Image Processing Toolbox.

$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

$$\mathtt{f}=\begin{bmatrix} \mathtt{f(1,1)} & \mathtt{f(1,2)} & \cdots & \mathtt{f(1,N)} \\ \mathtt{f(2,1)} & \mathtt{f(2,2)} & \cdots & \mathtt{f(2,N)} \\ \vdots & \vdots & & \vdots \\ \mathtt{f(M,1)} & \mathtt{f(M,2)} & \cdots & \mathtt{f(M,N)} \end{bmatrix}$$

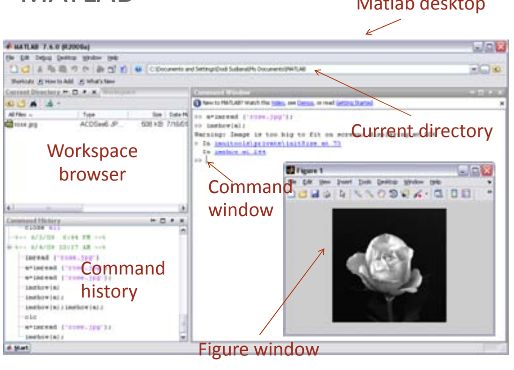
Format citra MATLAB®

TABLE 2.1 Some of the image/graphics formats supported by `imread` and `imwrite`, starting with MATLAB 6.5. Earlier versions support a subset of these formats. See online help for a complete list of supported formats.

Format Name	Description	Recognized Extensions
TIFF	Tagged Image File Format	`.tif`, `.tiff`
JPEG	Joint Photographic Experts Group	`.jpg`, `.jpeg`
GIF	Graphics Interchange Format[†]	`.gif`
BMP	Windows Bitmap	`.bmp`
PNG	Portable Network Graphics	`.png`
XWD	X Window Dump	`.xwd`

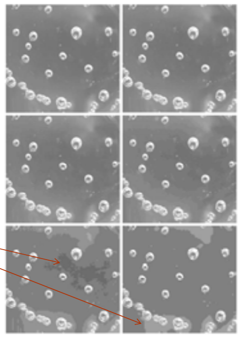
[†] `GIF` is supported by `imread`, but not by `imwrite`.

MATLAB®



JPEG Quality Settings

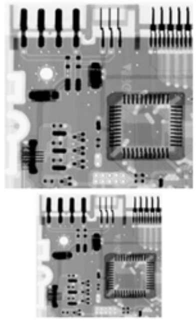
(a) Original Image
(b) JPEG Quality=50
(c) JPEG Quality=25
(d) JPEG Quality=15
(e) JPEG Quality=5
(f) JPEG Quality=0



False contouring

Rescaling image resolution

(a) 450 x 450 pixels; 200 dpi (size= 2.25 x 2.25 inches)
(b) 450 x 450 pixels; 300 dpi (size= 1.5 x 1.5 inches)



■ Figure 2.5(a) is an 8-bit X-ray image of a circuit board generated during quality inspection. It is in `jpg` format, at 200 dpi. The image is of size 450 × 450 pixels, so its dimensions are 2.25 × 2.25 inches. We want to store this image in `tif` format, with no compression, under the name `sf`. In addition, we want to reduce the size of the image to 1.5 × 1.5 inches while keeping the pixel count at 450 × 450. The following statement yields the desired result:

```
>> imwrite(f,'sf.tif','compression','none','resolution', ...
                                                  [300 300])
```

The values of the vector `[colres rowres]` were determined by multiplying 200 dpi by the ratio 2.25/1.5, which gives 300 dpi. Rather than do the computation manually, we could write

```
>> res = round(200*2.25/1.5);
>> imwrite(f, 'sf.tif', 'compression', 'none' ,'resolution', res)
```

Data classes

numeric classes
char class
logical class

Name	Description
`double`	Double-precision, floating-point numbers in the approximate range -10^{308} to 10^{308} (8 bytes per element).
`uint8`	Unsigned 8-bit integers in the range [0, 255] (1 byte per element).
`uint16`	Unsigned 16-bit integers in the range [0, 65535] (2 bytes per element).
`uint32`	Unsigned 32-bit integers in the range [0, 4294967295] (4 bytes per element).
`int8`	Signed 8-bit integers in the range [−128, 127] (1 byte per element).
`int16`	Signed 16-bit integers in the range [−32768, 32767] (2 bytes per element).
`int32`	Signed 32-bit integers in the range [−2147483648, 2147483647] (4 bytes per element).
`single`	Single-precision floating-point numbers with values in the approximate range -10^{38} to 10^{38} (4 bytes per element).
`char`	Characters (2 bytes per element).
`logical`	Values are 0 or 1 (1 byte per element).

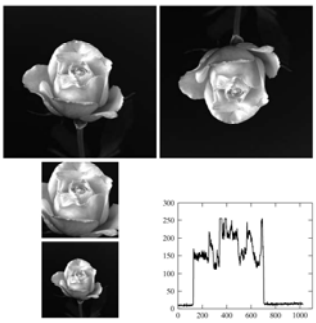
Image to types conversion

Name	Converts Input to:	Valid Input Image Data Classes
`im2uint8`	`uint8`	`logical`, `uint8`, `uint16`, and `double`
`im2uint16`	`uint16`	`logical`, `uint8`, `uint16`, and `double`
`mat2gray`	`double` (in range [0, 1])	`double`
`im2double`	`double`	`logical`, `uint8`, `uint16`, and `double`
`im2bw`	`logical`	`uint8`, `uint16`, and `double`

Array indexing

a b
c
d e

FIGURE 2.6 Results obtained using array indexing. (a) Original image. (b) Image flipped vertically. (c) Cropped image. (d) Subsampled image. (e) A horizontal scan line through the middle of the image in (a).



Array and matrix arithmatic

Function	Description
`imadd`	Adds two images; or adds a constant to an image.
`imsubtract`	Subtracts two images; or subtracts a constant from an image.
`immultiply`	Multiplies two images, where the multiplication is carried out between pairs of corresponding image elements; or multiplies a constant times an image.
`imdivide`	Divides two images, where the division is carried out between pairs of corresponding image elements; or divides an image by a constant.
`imabsdiff`	Computes the absolute difference between two images.
`imcomplement`	Complements an image. See Section 3.2.1.
`imlincomb`	Computes a linear combination of two or more images. See Section 5.3.1 for an example.

Operator	Name	MATLAB Function	Comments and Examples
+	Array and matrix addition	`plus(A, B)`	a + b, A + B, or a + A.
–	Array and matrix subtraction	`minus(A, B)`	a – b, A – B, A – a, or a – A.
`.*`	Array multiplication	`times(A, B)`	`C = A.*B, C(I, J) = A(I, J)*B(I, J).`
`*`	Matrix multiplication	`mtimes(A, B)`	`A*B`, standard matrix multiplication, or `a*A`, multiplication of a scalar times all elements of `A`.
`./`	Array right division	`rdivide(A, B)`	`C = A./B, C(I, J) = A(I, J)/B(I, J).`
`.\`	Array left division	`ldivide(A, B)`	`C = A.\B, C(I, J) = B(I, J)/A(I, J).`
`/`	Matrix right division	`mrdivide(A, B)`	`A/B` is roughly the same as `A*inv(B)`, depending on computational accuracy.
`\`	Matrix left division	`mldivide(A, B)`	`A\B` is roughly the same as `inv(A)*B`, depending on computational accuracy.
`.^`	Array power	`power(A, B)`	If `C = A.^B`, then `C(I, J) = A(I, J)^B(I, J).`
`^`	Matrix power	`mpower(A, B)`	See online help for a discussion of this operator.
`.'`	Vector and matrix transpose	`transpose(A)`	`A.'`. Standard vector and matrix transpose.
`'`	Vector and matrix complex conjugate transpose	`ctranspose(A)`	`A'`. Standard vector and matrix conjugate transpose. When `A` is real `A.' = A'`.
+	Unary plus	`uplus (A)`	+A is the same as 0 + A.
–	Unary minus	`uminus (A)`	–A is the same as 0 – A or –1*A.
:	Colon		Discussed in Section 2.8.

Relational, logical operators & functions

Operator	Name
<	Less than
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
==	Equal to
~=	Not equal to

Operator	Name
&	AND
|	OR
~	NOT

Function	Comments
`xor` (exclusive OR)	The `xor` function returns a 1 only if both operands are logically different; otherwise `xor` returns a 0.
`all`	The `all` function returns a 1 if all the elements in a vector are nonzero; otherwise `all` returns a 0. This function operates columnwise on matrices.
`any`	The any function returns a 1 if any of the elements in a vector is nonzero; otherwise any returns a 0. This function operates columnwise on matrices.

Important variables & constants

Function	Value Returned
`ans`	Most recent answer (variable). If no output variable is assigned to an expression, MATLAB automatically stores the result in ans.
`eps`	Floating-point relative accuracy. This is the distance between 1.0 and the next largest number representable using double-precision floating point.
`i` (or `j`)	Imaginary unit, as in `1 + 2i`.
`NaN` or `nan`	Stands for Not-a-Number (e.g., `0/0`).
`pi`	3.14159265358979
`realmax`	The largest floating-point number that your computer can represent.
`realmin`	The smallest floating-point number that your computer can represent.
`computer`	Your computer type.
`version`	MATLAB version string.

Flow control

Statement	Description
`if`	`if`, together with `else` and `elseif`, executes a group of statements based on a specified logical condition.
`for`	Executes a group of statements a fixed (specified) number of times.
`while`	Executes a group of statements an indefinite number of times, based on a specified logical condition.
`break`	Terminates execution of a `for` or `while` loop.
`continue`	Passes control to the next iteration of a `for` or `while` loop, skipping any remaining statements in the body of the loop.
`switch`	`switch`, together with `case` and `otherwise`, executes different groups of statements, depending on a specified value or string.
`return`	Causes execution to return to the invoking function.
`try...catch`	Changes flow control if an error is detected during execution.