

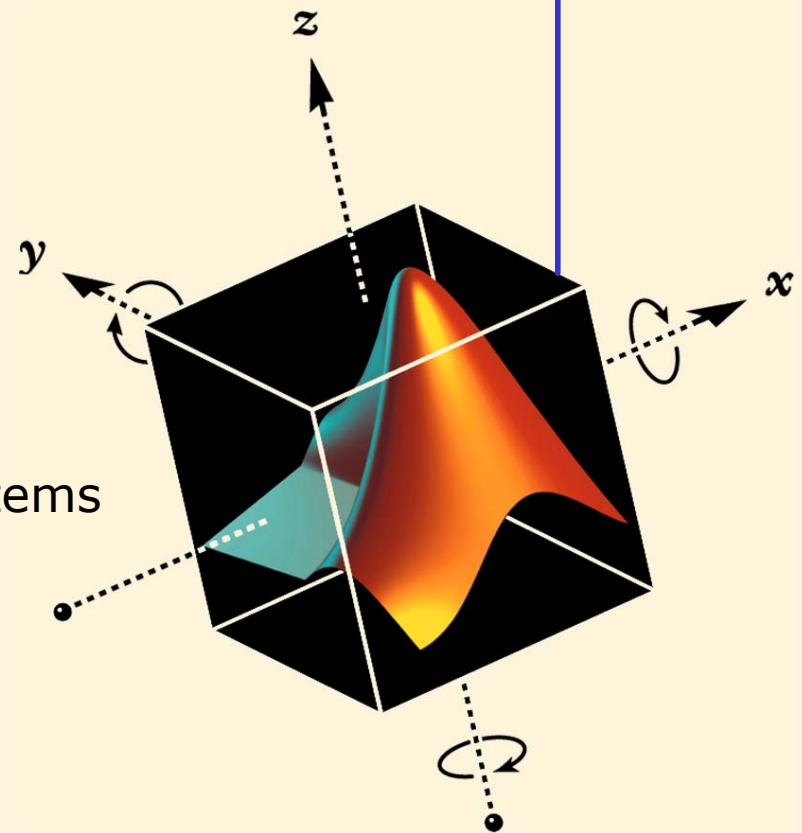
Introduction to Matlab

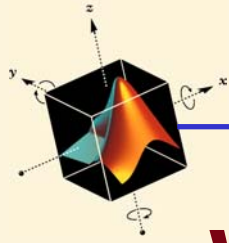
2E1215, Lecture 1 – Matlab Basics

<http://www.s3.kth.se/control/kurser/2E1215/>

Mikael Johansson and Frank Lingelbach
Department of Signals, Sensors and Systems

Based on lectures by F. Gustafsson, Linköping University



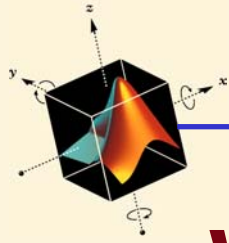


What is Matlab?

A software environment for interactive numerical computations

Examples:

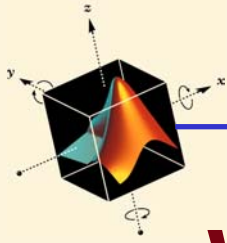
- Matrix computations and linear algebra
- Solving nonlinear equations
- Numerical solution of differential equations
- Mathematical optimization
- Statistics and data analysis
- Signal processing
- Modelling of dynamical systems
- Solving partial differential equations
- Simulation of engineering systems



What will you learn in 2E1215?

Effective Matlab usage

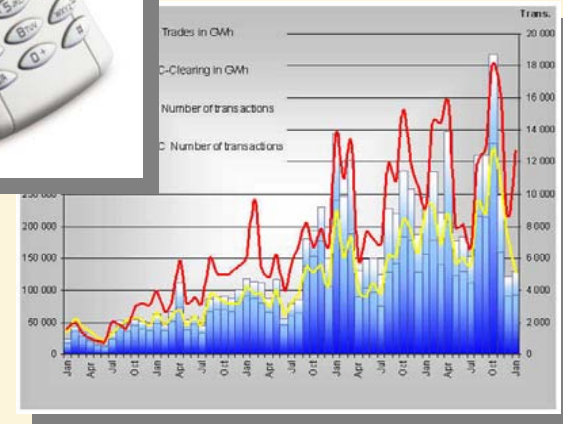
- Possibilities and limitations
- Syntax and interactive computations
- Matlab programming (using functions and script files)
- Visualization
- Optimization of code for efficient computations

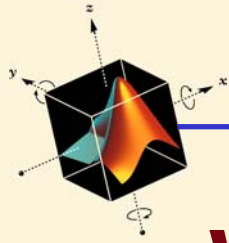


Introduction to Matlab

Why should you attend 2E1215?

Matlab used (on a daily basis) in many engineering companies

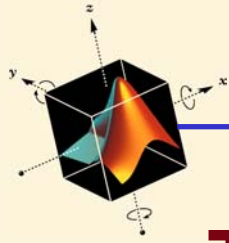




Why should you attend 2E1215?

Matlab used in many courses at KTH

2D1240	Numeriska metoder	2E1291	Kemiteknisk processreglering
5B1209	Signaler och system I	2E1241	Projektkurs i reglerteknik
2E1313	Signaler och system II	2E1421	Signalteori
2E1315	Signaler och system II, D	2E1340	Digital signalbehandling
2E1280	Modellering av dynamiska system	2E1350	Adaptiv signalbehandling
2E1200	Reglerteknik AK, F,M,T	2E1366	Projektkurs i signalbehandling
2E1211	Reglerteknik AK, E	2E1431	Kommunikationsteori
2E1252	Reglerteknik FK	2E1435	Kommunikationsteori FK
2E1262	Olinjär reglering	...	<många, många fler>



Today's Lecture

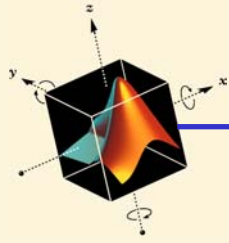
Course information

- Course contents and literature
- Course Guide

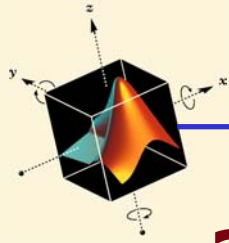
Matlab Basics

- Background to Matlab
- Interactive calculations
- Vectors and matrices
- Graphical illustrations

Next lecture: Matlab programming



Part I – Course Information



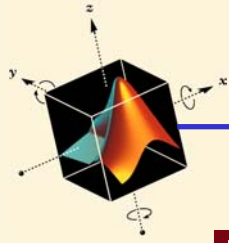
2E1215 – Introduction to Matlab

Student Handbook:

One (1) credit self study course. Eligible.

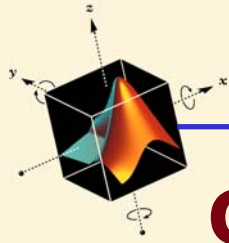
Objectives:

- Gain basic knowledge of Matlab programming
- To prepare for other courses where Matlab is used
- To give insight into a state-of-the-art tool for technical computation and visualization



Prerequisites

- Basic knowledge from calculus & linear algebra
- Basic programming skills (helpful, not necessary!)
- Internet and computer experience
- Curiosity!



Course Literature

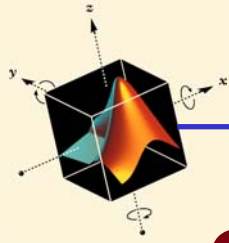
N. Bergman and F. Gustafsson, "**Matlab for Engineers Explained**", Springer, 2003

Available via k arbokhandeln

- Teaches practical Matlab usage (not a full manual)
- Basic description of theoretical concepts
- Based on examples with guided tours of the system
- Exercises with solutions
- Applications from engineering courses

Suggested exercises:

1-5, 8-17, 21, 23-32, 34, 37, 40-41, 44, 47-48



Course Guide

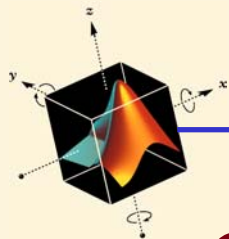
<http://www.s3.kth.se/control/kurser/2E1215/>

Schedule

Information

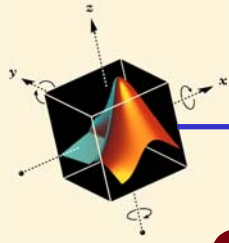
Registration

Examination



Course Guide - Registration





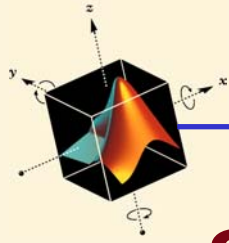
Course Guide - Registration

Registration is mandatory, both

- At the course webpage (to receive info, exam)
- At your "kansli" (computer account, credits in LADOK)

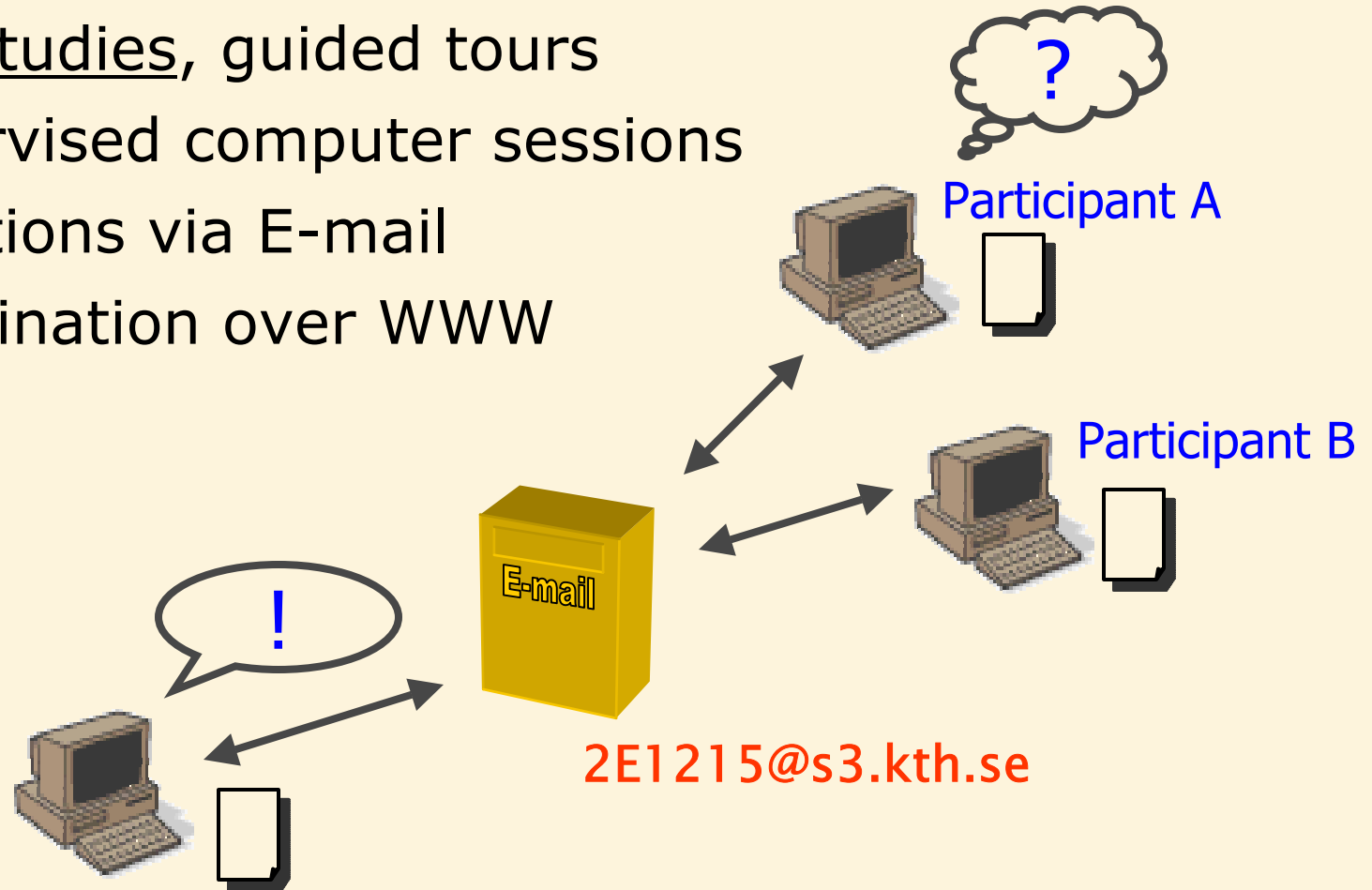
Take care of this today! (avoids frustration later)

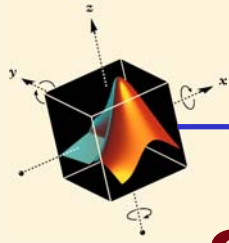
Note: "kansli" = "Study administrative office"



Studies

- Self studies, guided tours
- Supervised computer sessions
- Questions via E-mail
- Examination over WWW





Self studies - Availability

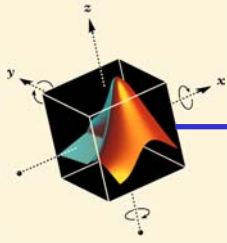
- The KTH CD-rom
- Matlab is installed in most computer labs

On Linux machines at Elektro type

```
module add matlab
```

```
matlab
```

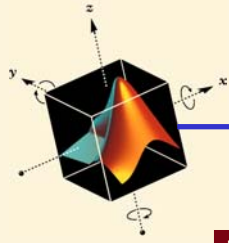
Any changes will be posted at course web page



Computer Exercises

You will need account at Elektro

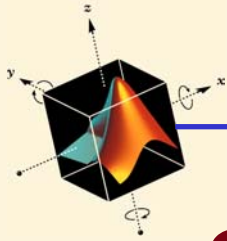
1. Register for course (necessary!)
2. Contact course administrator Magdalena Lindqvist, Osquldasv. 10, floor 6. (or email madde@s3.kth.se)
3. Two days later, the account can be checked out at Elhand, Osquldas v 10, floor 2.
 - bring identity card!



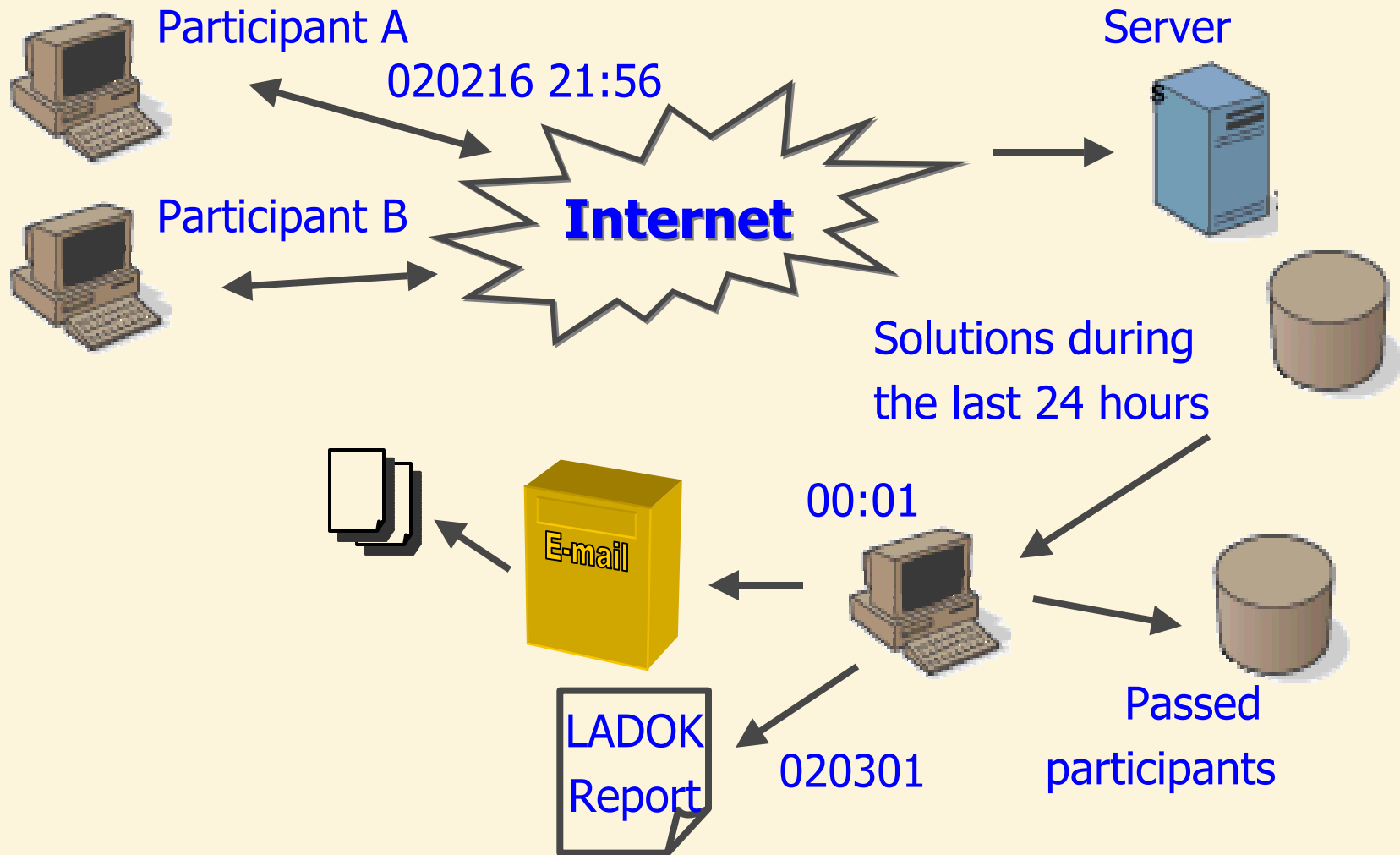
Exam via WWW

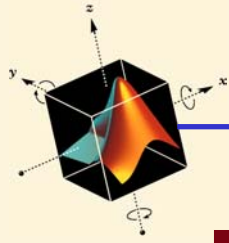
Distributed via WWW, executed in Matlab

1. Request exam from web-server
2. Allows you to download Matlab program that
 - a. Given your personal number, generate problems
 - b. Corrects and marks your code, returns string.
3. Submit string to server within 72 hours.
4. Grades via email.



Course Guide - Marks within 24h





More about the exam...

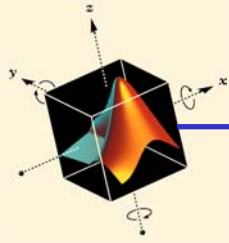
Do the exam!

- Most people that try the exam actually pass!
- You have 72 hours
- You can use all course material and the Matlab manuals!

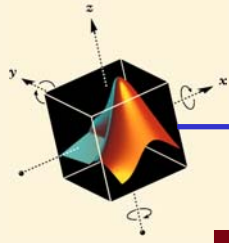
On the exam: four problems drawn from the categories

1. Basic matrix manipulations
2. Operations on string variables (not covered in lectures)
3. Writing functions
4. Flow control
5. Function functions

Program well – fast programs give higher score!



Part II – Matlab Basics



Matlab Background

Matlab = **Matrix Laboratory**

Originally a user interface for numerical linear algebra routines (Lapak/Linpak)

Commercialized 1984 by The Mathworks

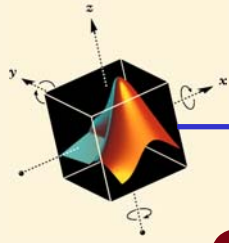
Since then heavily extended (defacto-standard)

Alternatives

Matrix-X	
Octave	(free; GNU)
Lyme	(free; Palm)

Complements

Maple	(symbolic)
Mathematica	(symbolic)



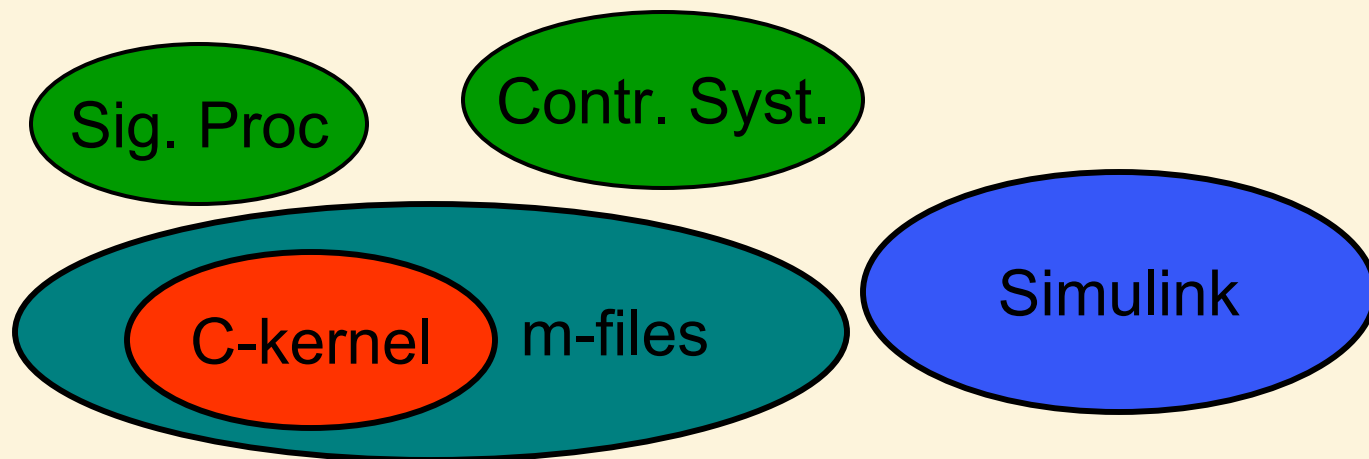
Construction

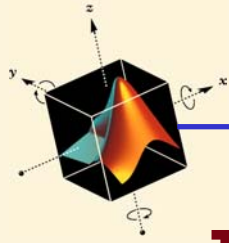
Core functionality: compiled C-routines

Most functionality is given as m-files, grouped into toolboxes

- m-files contain source code, can be copied and altered
- m-files are platform independent (PC, Unix/Linux, MAC)

Simulation of dynamical systems is performed in Simulink





Interactive Calculations

Matlab is interactive, no need to declare variables

```
>> 2+3*4/2
```

```
>> a=5e-3; b=1; a+b
```

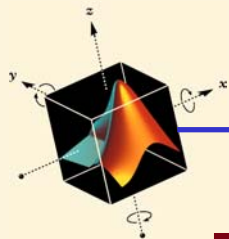
Most elementary functions and constants are already defined

```
>> cos(pi)
```

```
>> abs(1+i)
```

```
>> sin(pi)
```

Last call gives answer `1.2246e-016` !?



Floating point numbers in Matlab

IEEE Standard for double precision numbers



$$x = \pm(1 + f) \cdot 2^e$$

$$f = \frac{d_1}{2} + \frac{d_2}{2^2} + \dots + \frac{d_{52}}{2^{52}}$$

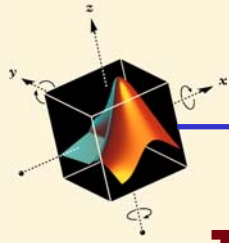
$$d_k = 0 \text{ or } 1$$

$$-1022 \leq e \leq 1023$$

Round-off: `eps` = 2^{-52}

Underflow: `realmin` = 2^{-1022}

Overflow: `realmax` = $(2 - \text{eps}) \cdot 2^{1023}$



Interactive Calculations

Matlab uses double precision (approx. 16 significant digits)

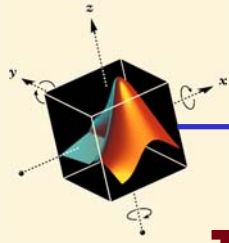
```
>> format long  
>> format compact
```

All variables are shown with

```
>> who  
>> whos
```

Variables can be stored on file

```
>> save filename  
>> clear  
>> load filename
```



Interactive Calculations

Search for appropriate function

```
>> lookfor keyword
```

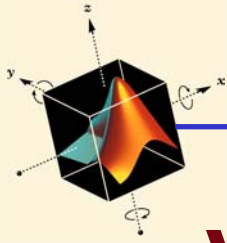
Rapid help with syntax and function definition

```
>> help function
```

An advanced hyperlinked help system is launched by

```
>> helpdesk
```

Complete manuals as PDF files



Vectors and Matrices

Vectors (arrays) are defined as

```
>> v = [1, 2, 4, 5]
```

```
>> w = [1; 2; 4; 5]
```

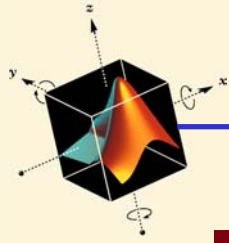
$$v = [1 \ 2 \ 4 \ 5]$$

$$w = \begin{bmatrix} 1 \\ 2 \\ 4 \\ 5 \end{bmatrix}$$

Matrices (2D arrays) defined similarly

```
>> A = [1,2,3;4,-5,6;5,-6,7]
```

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & -5 & 6 \\ 5 & -6 & 7 \end{bmatrix}$$



Matrix operators

All common operators are overloaded

```
>> v + 2
```

Common operators are available

```
>> B = A'
```

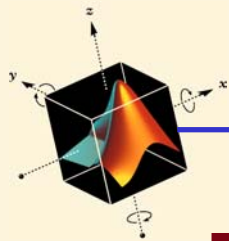
```
>> A*B
```

```
>> A+B
```

Note:

- Matlab is case-sensitive
 - `A` and `a` are two different variables
- Transponate conjugates complex entries; avoided by

```
>> B=A.'
```



Indexing Matrices

Indexing using parentheses

```
>> A(2,3)
```

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & -5 & 6 \\ 5 & 6 & 7 \end{bmatrix}$$

Index submatrices using vectors of row and column indices

```
>> A([2 3],[1 2])
```

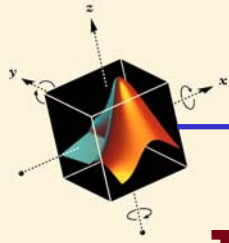
$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & -5 & 6 \\ 5 & 6 & 7 \end{bmatrix}$$

Ordering of indices is important!

```
>> B=A([3 2],[2 1])
```

```
>> B=[A(3,2),A(3,1);A(2,2);A(2,1)]
```

$$B = \begin{bmatrix} 6 & 5 \\ -5 & 4 \end{bmatrix}$$



Indexing Matrices

Index complete row or column using the colon operator

```
>> A(1, :)
```

Can also add limit index range

```
>> A(1:2, :)
```

```
>> A([1 2], :)
```

General notation for colon operator

```
>> v=1:5
```

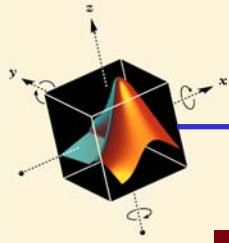
```
>> w=1:2:5
```

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & -5 & 6 \\ 5 & 6 & 7 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & -5 & 6 \\ 5 & 6 & 7 \end{bmatrix}$$

$$v = [1 \ 2 \ 3 \ 4 \ 5]$$

$$w = [1 \ 3 \ 5]$$



Matrix functions

Many elementary matrices predefined

```
>> help elmat;  
>> I=eye(3)
```

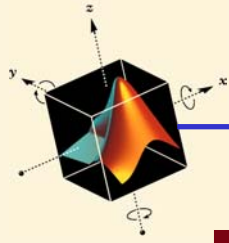
Elementary functions are often overloaded

```
>> help elmat  
>> sin(A)
```

Specialized matrix functions and operators

```
>> As=sqrtm(A)  
>> AS^2  
>> A.*A
```

Note: in general, "`.<operator>`" is elementwise operation



Numerical Linear Algebra

Basic numerical linear algebra

```
>> z=[1;2;3]; x=inv(A)*z
```

```
>> x=A\z
```

$$Ax = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$
$$x = A^{-1} \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$

Many standard functions predefined

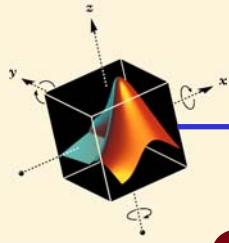
```
>> det(A)
```

```
>> rank(A)
```

```
>> eig(A)
```

The number of input/output arguments can often be varied

```
>> [V,D]=eig(A)
```

Graphics

Visualization of vector data is available

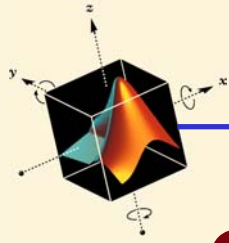
```
>> x=-pi:0.1:pi; y=sin(x);  
>> plot(x,y)  
>> plot(x,y,'s-')  
>> xlabel('x'); ylabel('y=sin(x)');
```

Can change plot properties in Figure menu, or via "handle"

```
>> h=plot(x,y); set(h, 'Linewidth', 4);
```

Many other plot functions available

```
>> v=1:4; pie(v)
```



Graphics

Three-dimensional graphics

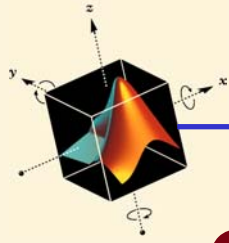
```
>> A = zeros(32);  
>> A(14:16,14:16) = ones(3);  
>> F=abs(fft2(A));  
>> mesh(F)  
>> rotate3d on
```

Several other plot functions available

```
>> surf1(F)
```

Can change lighting and material properties

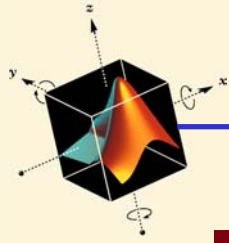
```
>> cameramenu  
>> material metal
```



Graphics

Bitmap images can also be visualized

```
>> load mandrill  
>> image(X); colormap(map)  
>> axis image off
```



Next Lecture

Programming in MATLAB

