Intelligenza Artificiale

Anno Accademico 2008-2009

Introduzione alla Visione Artiificiale

Sommario

- Introduzione
- Percezione
- Formazione delle immagini
- Elaborazione delle immagini a basso livello
- Estrazione di informazione 3D da un’immagine
- Riconoscimento di oggetti
- Manipolazione e navigazione
- Conclusioni

Sommario

- Introduzione
- Percezione
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Visione e CV

- La *Visione* è il senso che consente all'essere umano di inferire il mondo 3D, di localizzare e riconoscere gli oggetti presenti in una scena, di percepire i rapidi mutamenti dell'ambiente, ...
- La *Visione Artificiale (Visione Computazionale, Computer Vision (CV))* è la disciplina che studia modelli e metodi per abilitare le macchine alla comprensione e interpretazione delle informazioni visuali presenti in immagini fisse o in sequenze video

Visione e CV

- L'occhio raccoglie una banda di *radiazioni elettromagnetiche* riflesse dalle superfici che costituiscono la scena e provenienti da fonti luminose diverse
- Il cervello elabora le informazioni raccolte e costruisce il quadro della scena come noi la percepiamo
- La CV si occupa della *analisi* di immagini numeriche al calcolatore
- L'analisi è finalizzata a scoprire *cosa* è presente nella scena e *dove*

Computer Vision

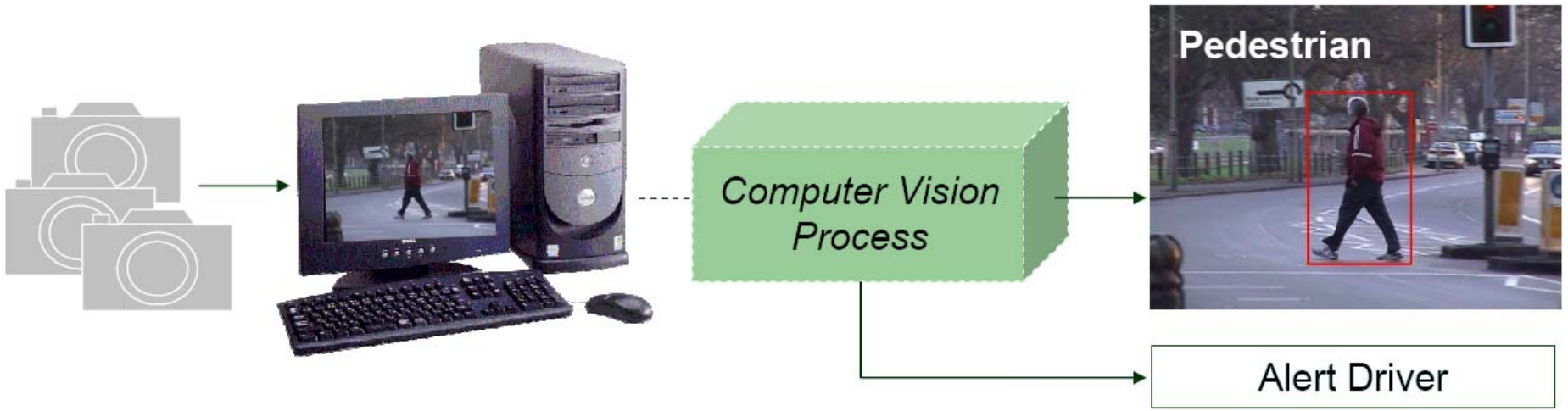
Computer Vision ≠ Image Processing

Computer Vision ≠ Pattern Recognition

- *Elaborazione di immagini:* miglioramento *(enhancement)*, restauro e compressione di immagini; si elabora un'immagine per ottenerne un'altra "migliore"
- *Riconoscimento di forme:* (estrazione), identificazione e classificazione di caratteristiche presenti nelle immagini

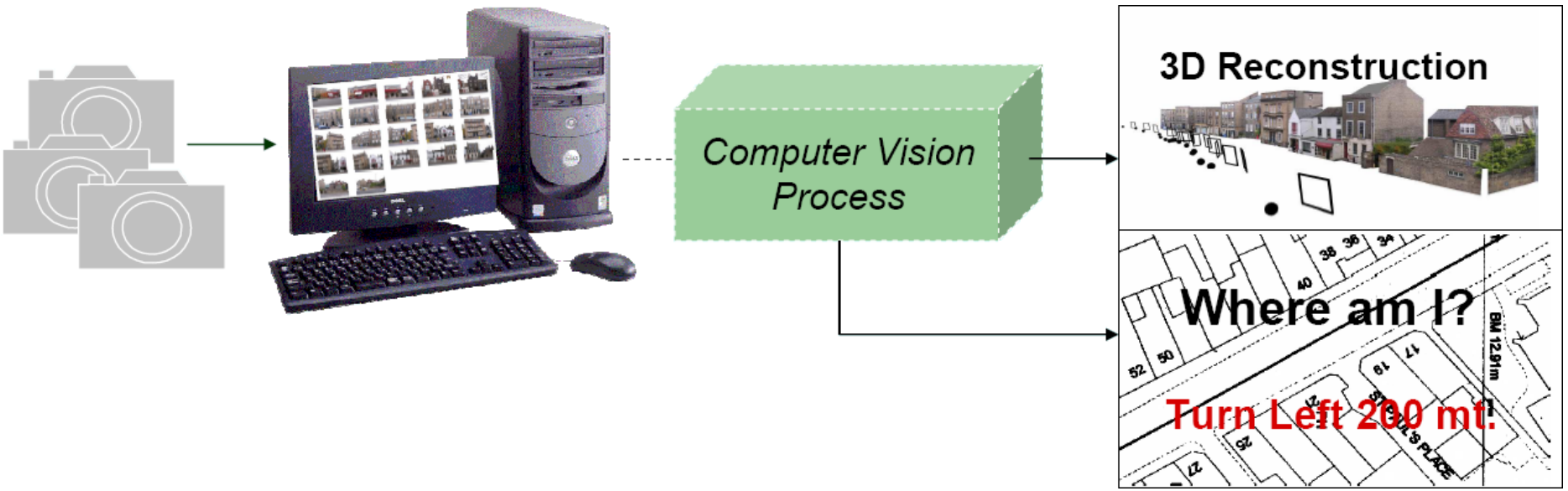
Sistemi CV

Un computer elabora immagini di una scena reale, catturate da una o più (tele)camere, ed estrae da esse informazioni al fine di prendere *decisioni* in maniera automatica o semiautomatica



Sistemi CV

Un computer elabora immagini di una scena reale, catturate da una o più (tele)camere, per ottenere una *interpretazione* 3D della scena. Anche in questo caso tale informazione può essere utilizzata per prendere *decisioni* in maniera automatica o semiautomatica



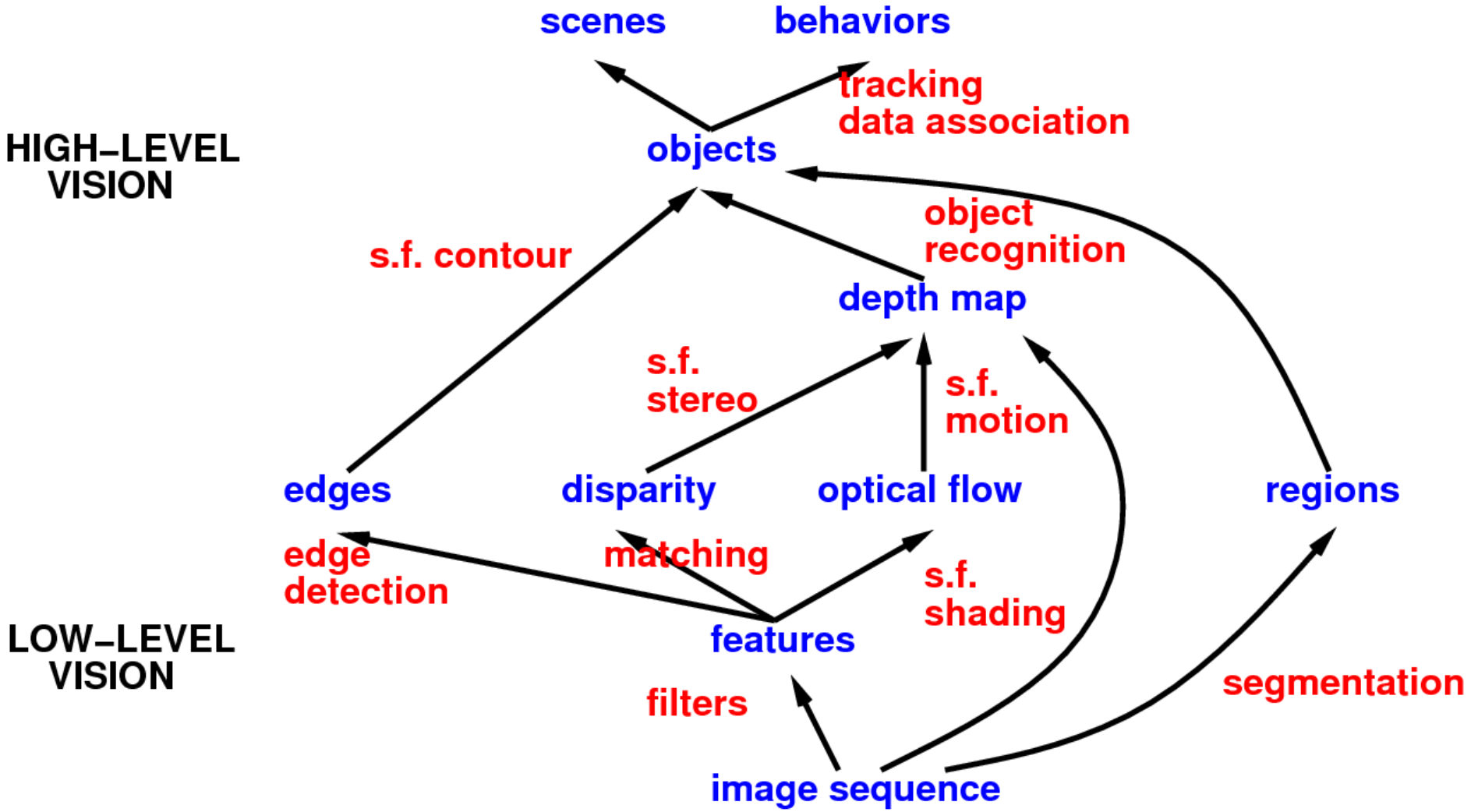
Obiettivi CV

- Realizzare sistemi capaci di prendere decisioni a partire da una descrizione della scena estrapolata da immagini fisse e/o sequenze video
- Inferire il mondo 3D a partire da immagini digitali
- Riconoscere oggetti, scene, contesto, a partire da immagini digitali
- ...

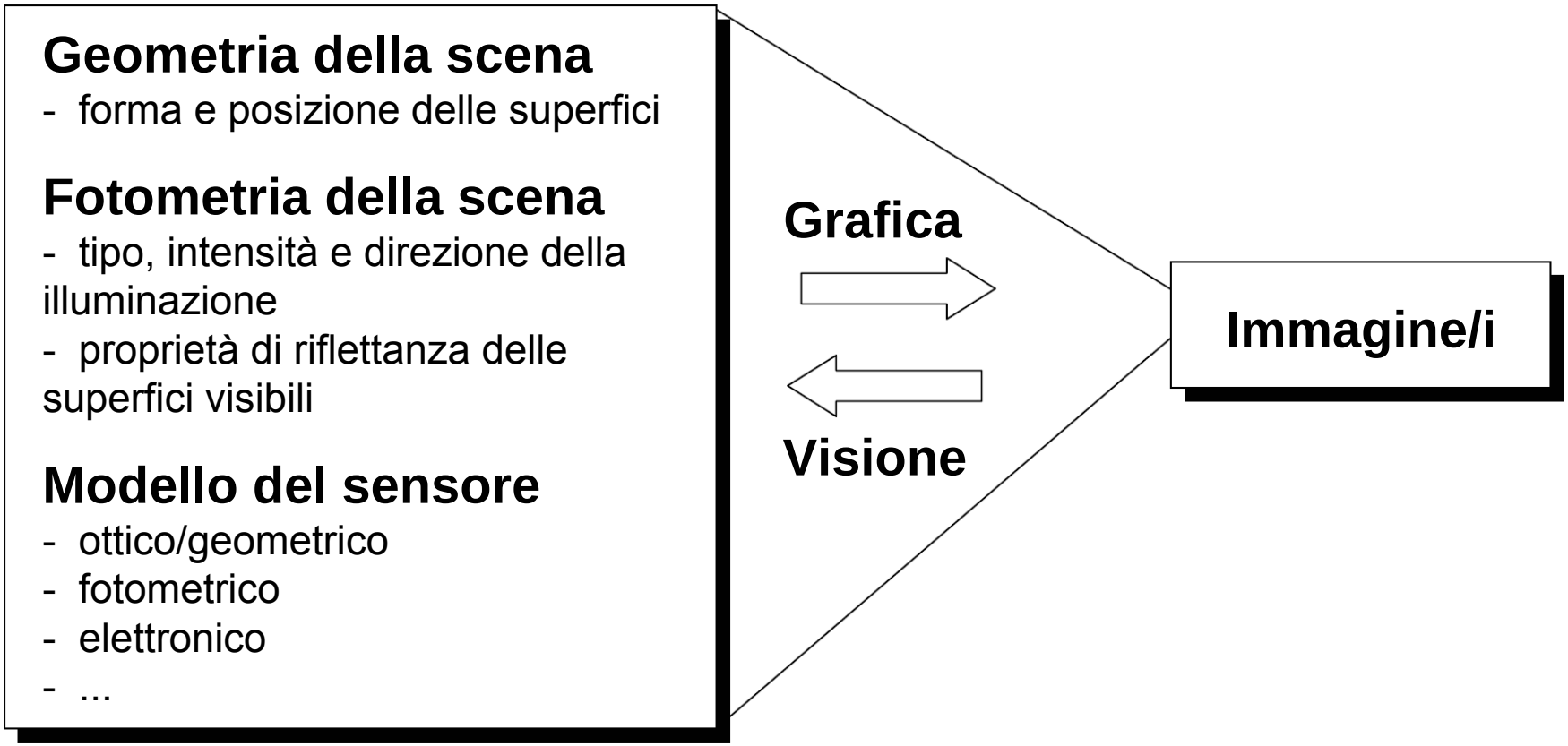
Computer Vision

- CV di basso livello
  - Estrazione di primitive geometriche, forma, profondità, dimensione, contorni degli oggetti, ...
  - Inverso della Grafica Computerizzata
  - Processi paralleli, spazialmente uniformi, indipendenti dal problema e dalla conoscenza a priori
- CV di alto livello *(Image Understanding)*
  - Estrazione delle proprietà delle forme
  - Studio delle loro relazioni spaziali
  - Classificazione e riconoscimento di oggetti
  - Processi applicati a porzioni dell'immagine, dipendenti dall'obiettivo e dalla conoscenza a priori

Computer Vision



Visione e Grafica



Problematiche

- *Variazioni nelle Condizioni di illuminazione:* producono variazioni nella distribuzione dell'intensità luminosa all'interno della scena
- *Trasformazioni geometriche rigide degli oggetti*
  - roto-traslazioni e variazioni di scala in 2D
  - roto-traslazioni e variazioni di scala in 3D
- *Rumore*
- *Gap:* tipo di rumore consistente nella mancanza di elementi nell'immagine
- *Occlusioni*

Problematiche

- *Segmentazione:* partizionamento dei dati in input in entità semantiche differenti (linee, regioni, oggetti, ...)
- *Indexing:* ricerca efficiente in un catalogo di modelli
- *Identificazione:* riconoscimento dell'istanza di un oggetto in un'immagine
- *Classificazione:* riconoscimento dell'appartenenza ad una data classe di un oggetto in un'immagine
- *Oggetti non rigidi:* il riconoscimento è complicato dalla possibilità della loro forma di variare (forbici, volti, ...)

Applicazioni industriali CV

- Automobile driver assistance
  - Vision systems that warn automobile drivers of danger, provide adaptive cruise control and give driver assistance
- Automobile traffic management
  - Systems for reading automobile license plates
- Film and video
  - Systems for tracking objects in video or film to provide enhancement broadcasts
- General purpose vision systems
  - Vision systems for object recognition and navigation; applications include mobile robotics, and recognition from cell phone cameras
- Image search
  - Content-Based Image Retrieval (CBIR)

Applicazioni industriali CV

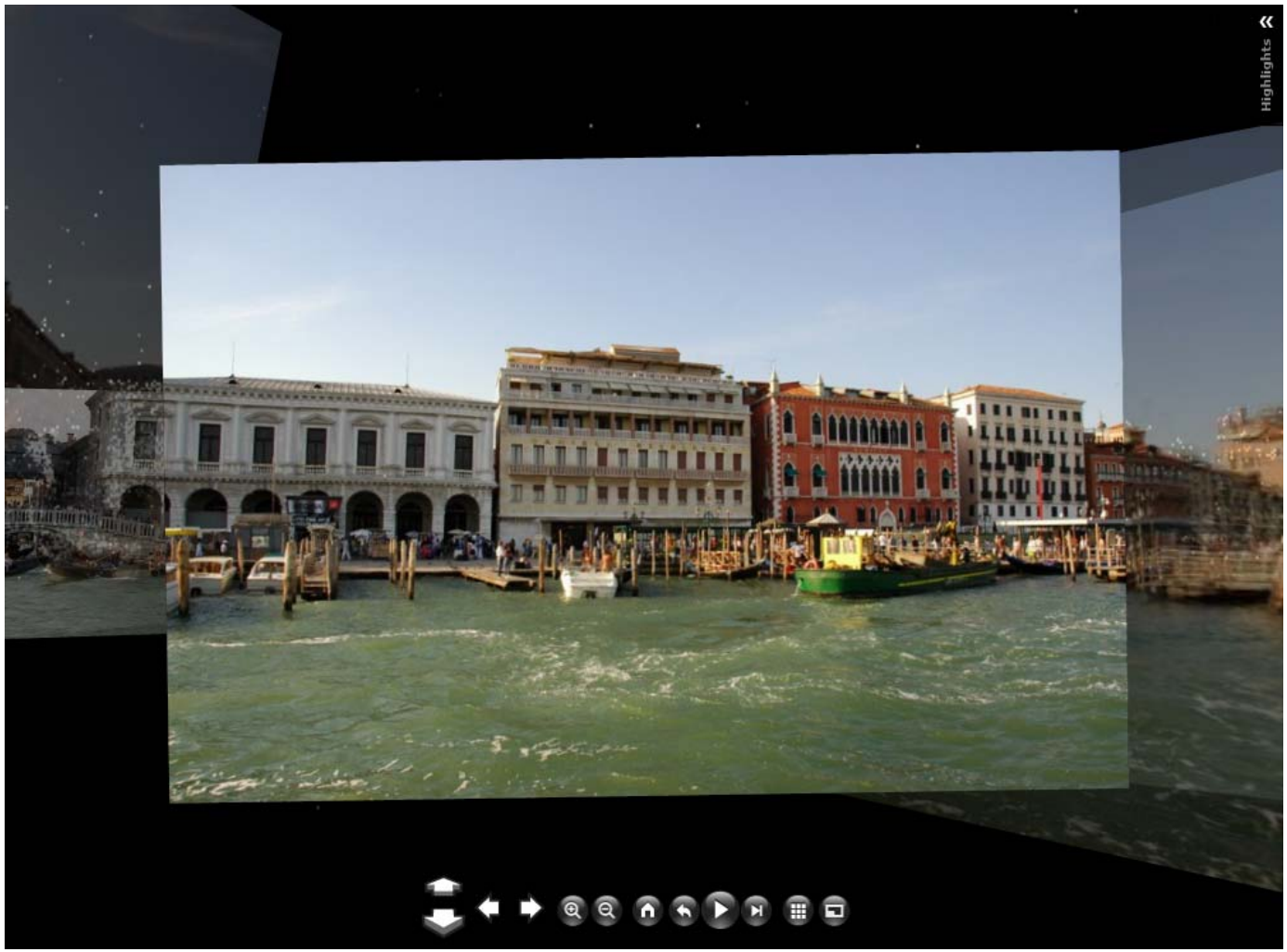
- Industrial automation and inspection
  - **Automotive industry:** systems for vision-guided robotics in the automotive industry and other robotics applications
  - **Electronics industry:** electronics inspection systems for component assembly and semiconductor manufacturing
  - **Food and agriculture:** vision systems for inspecting and grading fruits and vegetables
  - **Printing and textiles:** inspection for the printing and packaging industries
- Medical and biomedical
  - Systems of real-time stereo vision to detect and track the pose of markers for surgical applications
- People tracking
  - Systems for counting and tracking pedestrians using overhead cameras

Applicazioni industriali CV

- Safety monitoring
  - Systems for monitoring swimming pools to warn of accidents and drowning victims
- Security
  - Systems for intelligent video surveillance, including tracking, object monitoring, and behavior analysis
- Biometrics
  - Systems for fingerprint, iris, and face recognition
- Three-dimensional modeling
  - Creation of texture-mapped 3D models from a small number of photographs
- Video games
  - Tracking of human gestures for playing games or interacting with pc

Demo

- Visualizzazione di fotografie in un ambiente 3D virtuale
  - http://labs.live.com/photosynth/collectionHome.htm



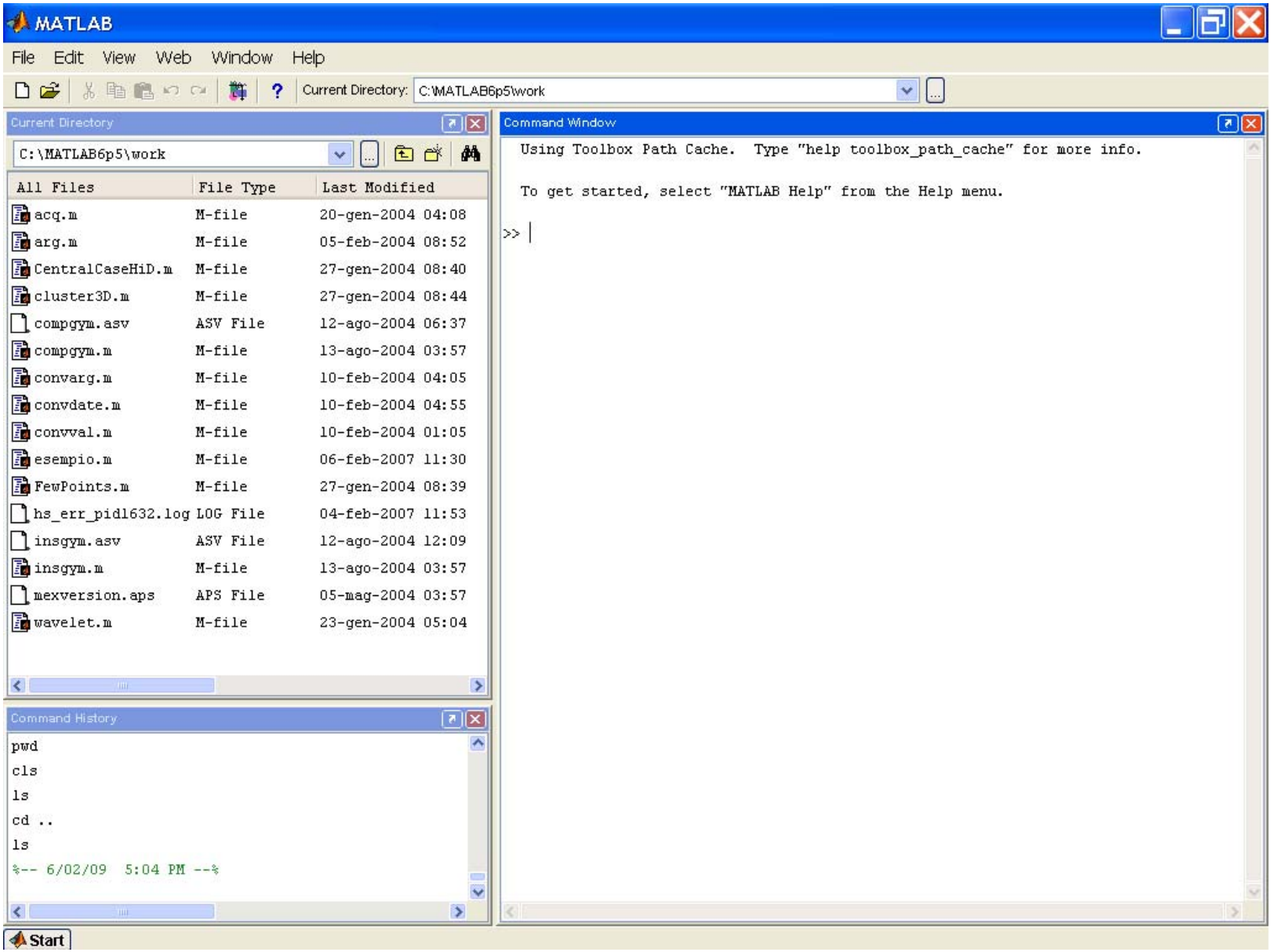
Link in Rete

- The Computer Vision Home Page
  - http://www.cs.cmu.edu/~cil/vision.html
- Computer Vision Education
  - http://www.cved.org
- The Computer Vision Industry
  - http://www.cs.ubc.ca/spider/lowe/vision.html
- CVOnLine
  - http://homepages.inf.ed.ac.uk/rbf/CVonline
- Annotated Computer Vision Bibliography
  - http://iris.usc.edu/Vision-Notes/bibliography/contents.html

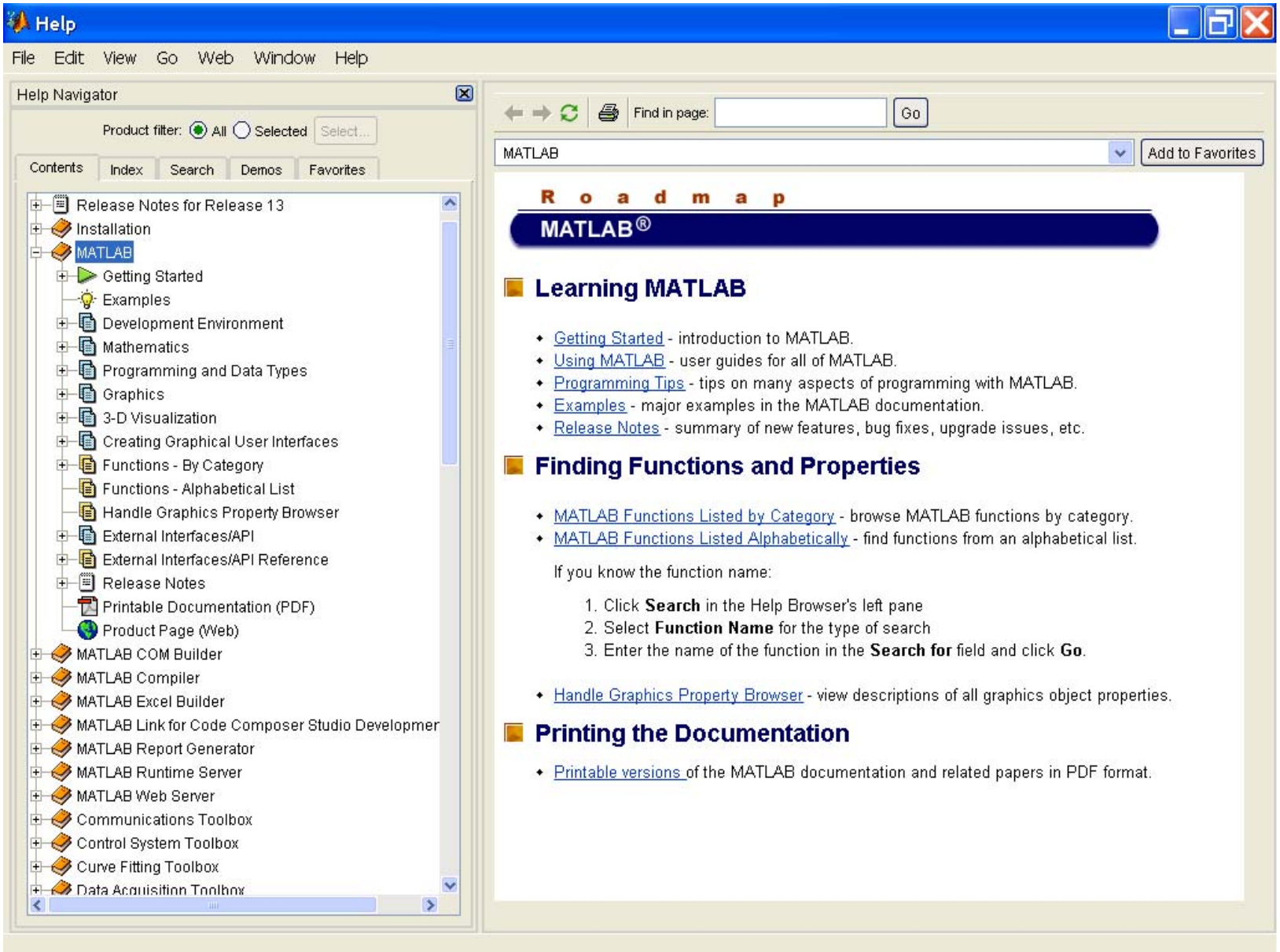
Riviste e convegni principali

- Convegni
  - ICCV, ECCV, CVPR, SIGGRAPH, ICPR, ICIP
- Riviste (journal)
  - International Journal on Computer Vision
  - IEEE Transactions on Pattern Analysis & Machine Intelligence (PAMI)
  - Computer Vision and Image Understanding (CVIU)
  - Image and Vision Computing
  - Machine Vision & Applications
  - IEEE Transactions on Image Processing
  - Pattern Recognition
  - Pattern Recognition Letters

Matlab


MATLAB
File Edit View Web Window Help
Current Directory: C:\MATLAB6p5\work
Current Directory
C:\MATLAB6p5\work
All Files File Type Last Modified
acq.m M-file 20-gen-2004 04:08
arg.m M-file 05-feb-2004 08:52
CentralCaseHiD.m M-file 27-gen-2004 08:40
cluster3D.m M-file 27-gen-2004 08:44
compgym.asv ASV File 12-ago-2004 06:37
compgym.m M-file 13-ago-2004 03:57
convarg.m M-file 10-feb-2004 04:05
convdate.m M-file 10-feb-2004 04:55
convval.m M-file 10-feb-2004 01:05
esempio.m M-file 06-feb-2007 11:30
FewPoints.m M-file 27-gen-2004 08:39
hs_err_pid1632.log LOG File 04-feb-2007 11:53
insgym.asv ASV File 12-ago-2004 12:09
insgym.m M-file 13-ago-2004 03:57
mexversion.aps APS File 05-mag-2004 03:57
wavelet.m M-file 23-gen-2004 05:04
Command History
pwd
cls
ls
cd ..
ls
%-- 6/02/09 5:04 PM --%
Command Window
Using Toolbox Path Cache. Type "help toolbox_path_cache" for more info.
To get started, select "MATLAB Help" from the Help menu.
>>
Start

Matlab


Help
File Edit View Go Web Window Help
Help Navigator
Product filter: All Selected Select...
Contents Index Search Demos Favorites
Release Notes for Release 13
Installation
MATLAB
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Development Environment
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Handle Graphics Property Browser
External Interfaces/API
External Interfaces/API Reference
Release Notes
Printable Documentation (PDF)
Product Page (Web)
MATLAB COM Builder
MATLAB Compiler
MATLAB Excel Builder
MATLAB Link for Code Composer Studio Developmer
MATLAB Report Generator
MATLAB Runtime Server
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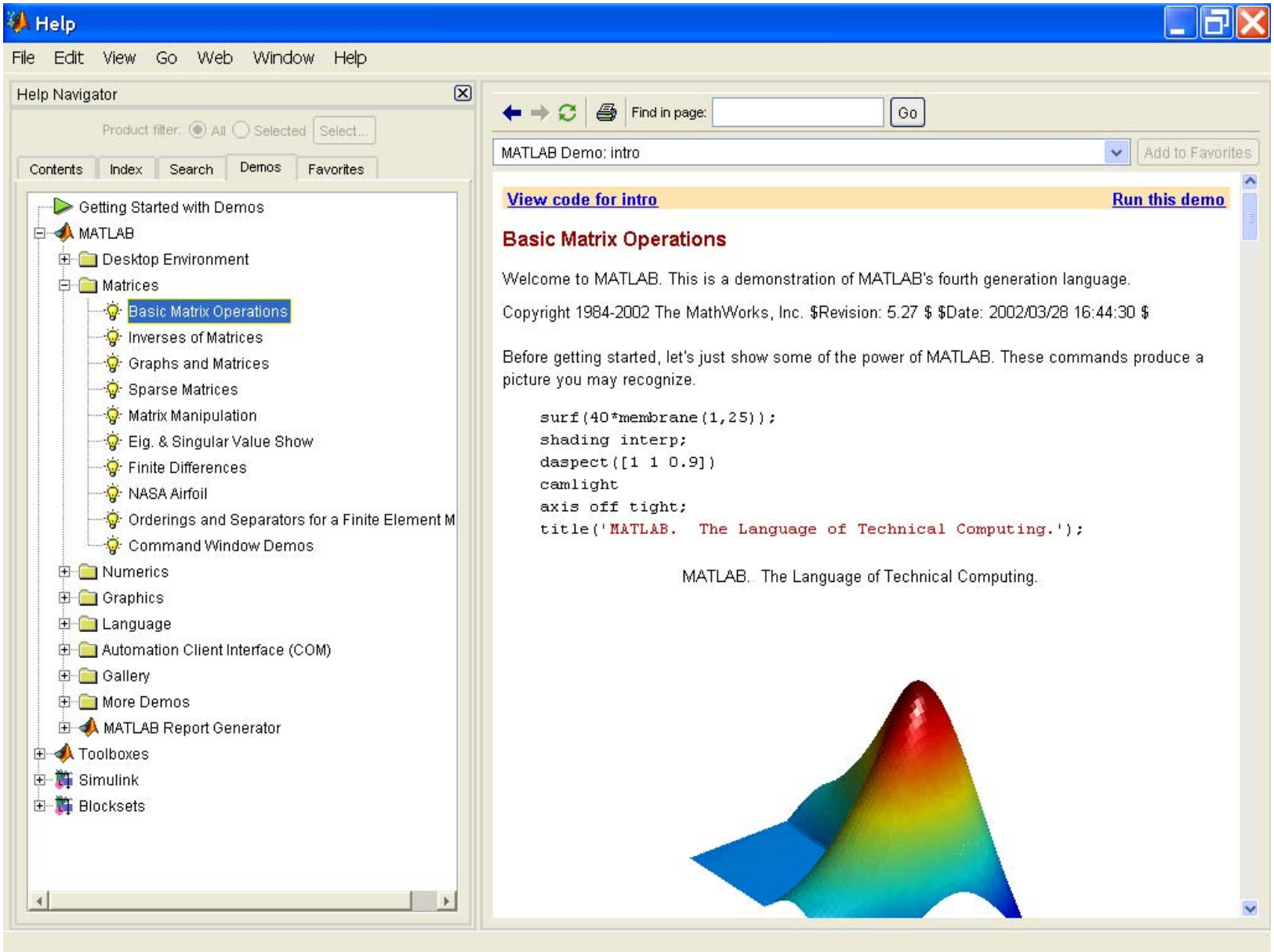
Learning MATLAB
Getting Started - introduction to MATLAB.
Using MATLAB - user guides for all of MATLAB.
Programming Tips - tips on many aspects of programming with MATLAB.
Examples - major examples in the MATLAB documentation.
Release Notes - summary of new features, bug fixes, upgrade issues, etc.
Finding Functions and Properties
MATLAB Functions Listed by Category - browse MATLAB functions by category.
MATLAB Functions Listed Alphabetically - find functions from an alphabetical list.
If you know the function name:
1. Click Search in the Help Browser's left pane
2. Select Function Name for the type of search
3. Enter the name of the function in the Search for field and click Go.
Handle Graphics Property Browser - view descriptions of all graphics object properties.
Printing the Documentation
Printable versions of the MATLAB documentation and related papers in PDF format.

Matlab


Help
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Getting Started with Demos
MATLAB
Desktop Environment
Matrices
Basic Matrix Operations
Inverses of Matrices
Graphs and Matrices
Sparse Matrices
Matrix Manipulation
Eig. & Singular Value Show
Finite Differences
NASA Airfoil
Orderings and Separators for a Finite Element M
Command Window Demos
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Go
MATLAB Demo: intro
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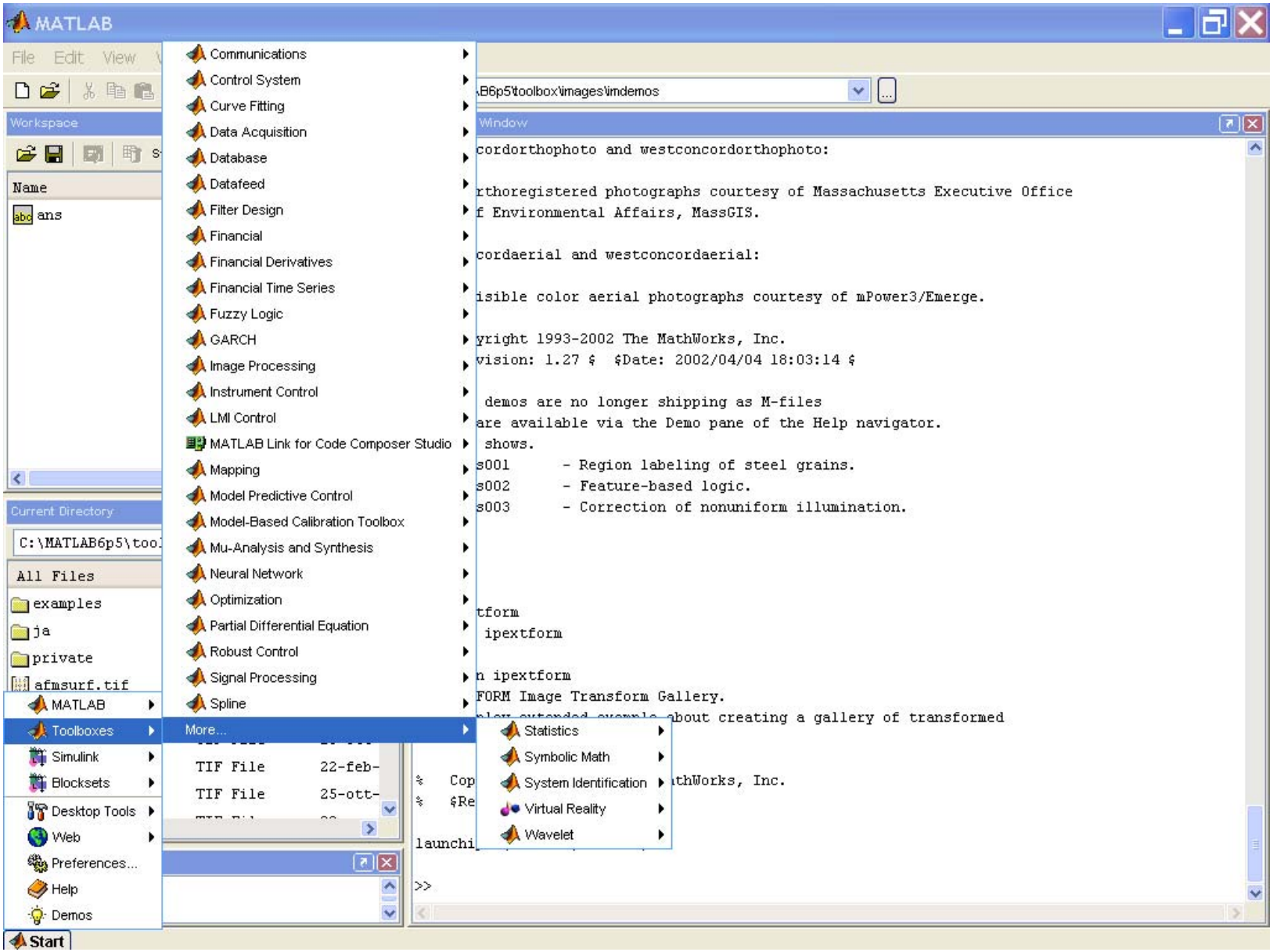
View code for intro
Run this demo
Basic Matrix Operations
Welcome to MATLAB. This is a demonstration of MATLAB's fourth generation language.
Copyright 1984-2002 The MathWorks, Inc. $Revision: 5.27 $ $Date: 2002/03/28 16:44:30 $
Before getting started, let's just show some of the power of MATLAB. These commands produce a picture you may recognize.
surf(40*membrane(1,25));
shading interp;
daspect([1 1 0.9])
camlight
axis off tight;
title('MATLAB. The Language of Technical Computing.');
MATLAB. The Language of Technical Computing.

Matlab


MATLAB
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Workspace
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All Files
examples
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MATLAB
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Simulink
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Desktop Tools
Web
Preferences...
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Control System
Curve Fitting
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Filter Design
Financial
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Financial Time Series
Fuzzy Logic
GARCH
Image Processing
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LMI Control
MATLAB Link for Code Composer Studio
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Model Predictive Control
Model-Based Calibration Toolbox
Mu-Analysis and Synthesis
Neural Network
Optimization
Partial Differential Equation
Robust Control
Signal Processing
Spline
More...
Statistics
Symbolic Math
System Identification
Virtual Reality
Wavelet
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Window
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f Environmental Affairs, MassGIS.
cordaerial and westconcordaerial:
isible color aerial photographs courtesy of mPower3/Emerge.
yright 1993-2002 The MathWorks, Inc.
vision: 1.27 $ $Date: 2002/04/04 18:03:14 $
demos are no longer shipping as M-files
are available via the Demo pane of the Help navigator.
shows.
s001 - Region labeling of steel grains.
s002 - Feature-based logic.
s003 - Correction of nonuniform illumination.
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FORM Image Transform Gallery.
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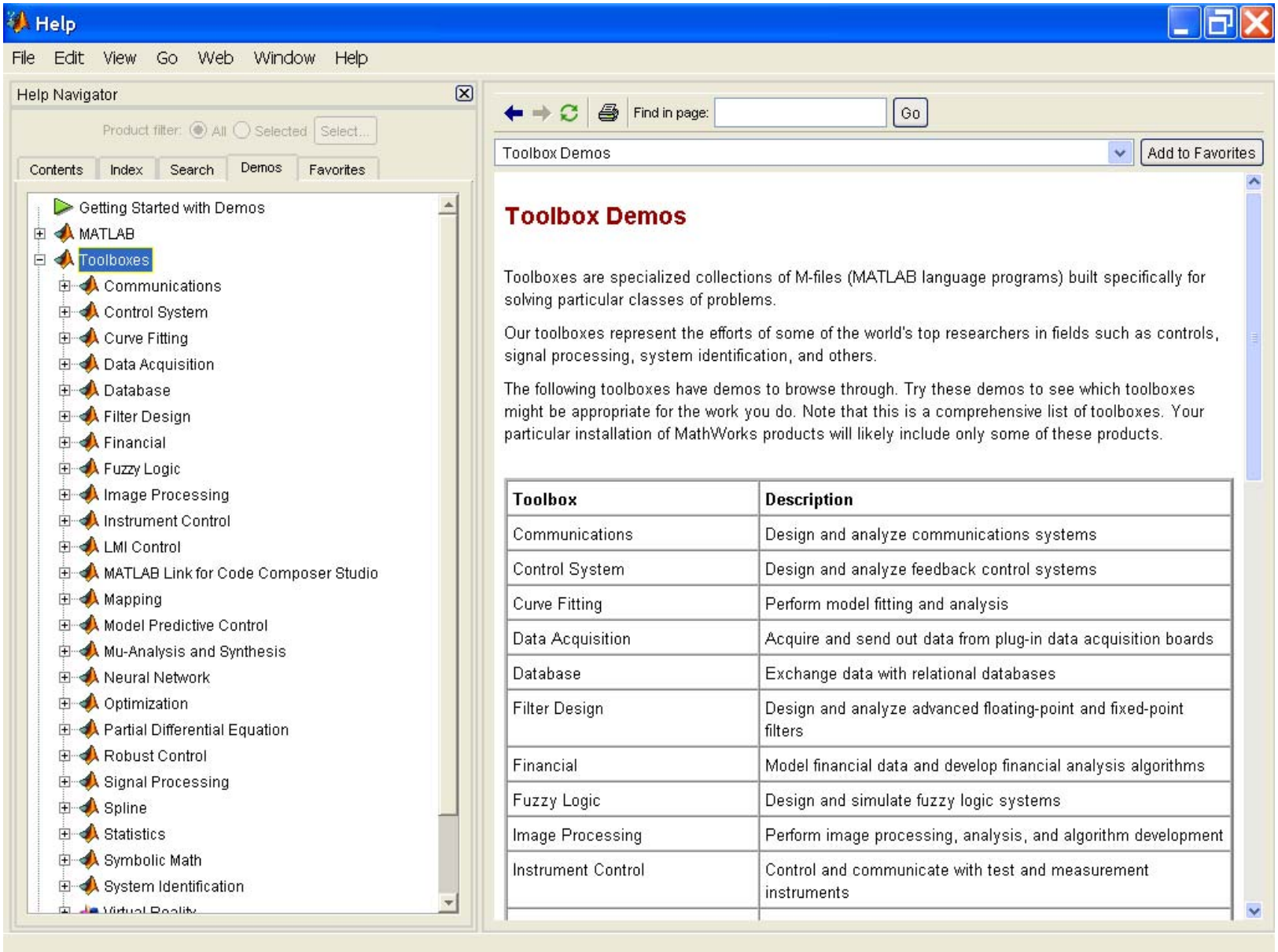
Matlab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Curve Fitting
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Filter Design
Financial
Fuzzy Logic
Image Processing
Instrument Control
LMI Control
MATLAB Link for Code Composer Studio
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Neural Network
Optimization
Partial Differential Equation
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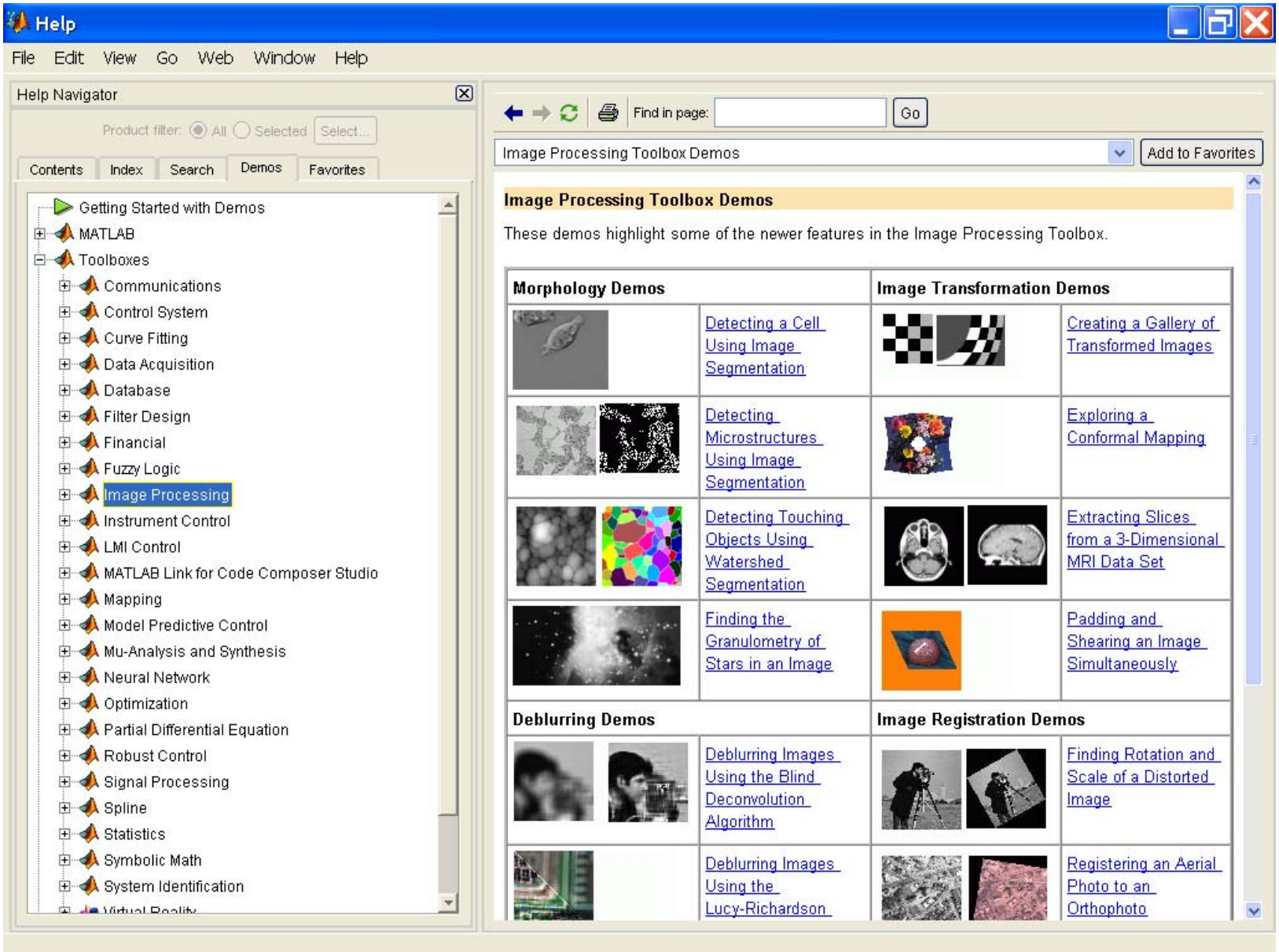
Toolboxes are specialized collections of M-files (MATLAB language programs) built specifically for solving particular classes of problems.
Our toolboxes represent the efforts of some of the world's top researchers in fields such as controls, signal processing, system identification, and others.
The following toolboxes have demos to browse through. Try these demos to see which toolboxes might be appropriate for the work you do. Note that this is a comprehensive list of toolboxes. Your particular installation of MathWorks products will likely include only some of these products.
Toolbox
Description
Communications
Design and analyze communications systems
Control System
Design and analyze feedback control systems
Curve Fitting
Perform model fitting and analysis
Data Acquisition
Acquire and send out data from plug-in data acquisition boards
Database
Exchange data with relational databases
Filter Design
Design and analyze advanced floating-point and fixed-point filters
Financial
Model financial data and develop financial analysis algorithms
Fuzzy Logic
Design and simulate fuzzy logic systems
Image Processing
Perform image processing, analysis, and algorithm development
Instrument Control
Control and communicate with test and measurement instruments

Matlab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These demos highlight some of the newer features in the Image Processing Toolbox.
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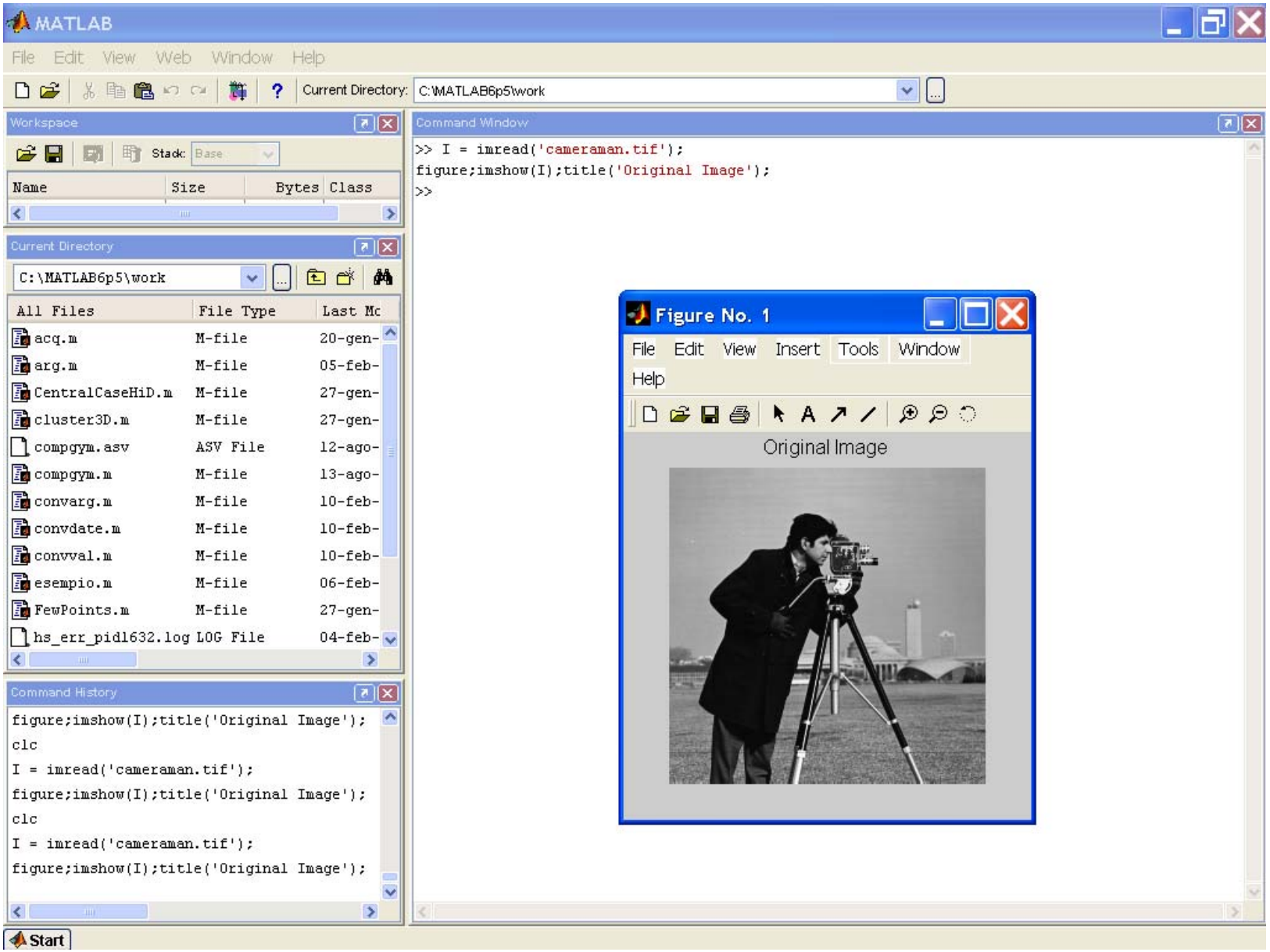
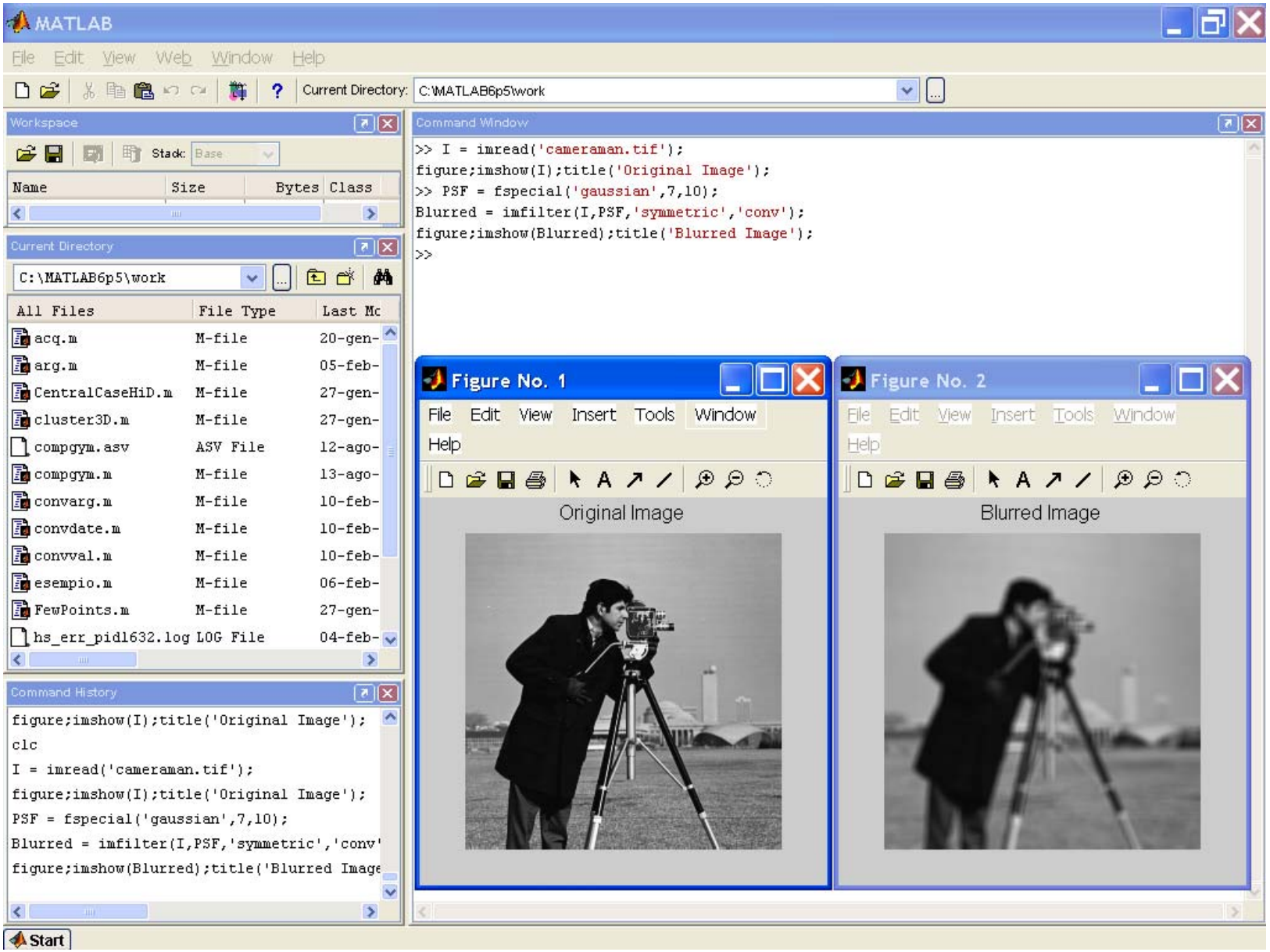
Detecting Microstructures Using Image Segmentation
Detecting Touching Objects Using Watershed Segmentation
Finding the Granulometry of Stars in an Image
Image Transformation Demos
Creating a Gallery of Transformed Images
Exploring a Conformal Mapping
Extracting Slices from a 3-Dimensional MRI Data Set
Padding and Shearing an Image Simultaneously
Deblurring Demos
Deblurring Images Using the Blind Deconvolution Algorithm
Deblurring Images Using the Lucy-Richardson
Image Registration Demos
Finding Rotation and Scale of a Distorted Image
Registering an Aerial Photo to an Orthophoto

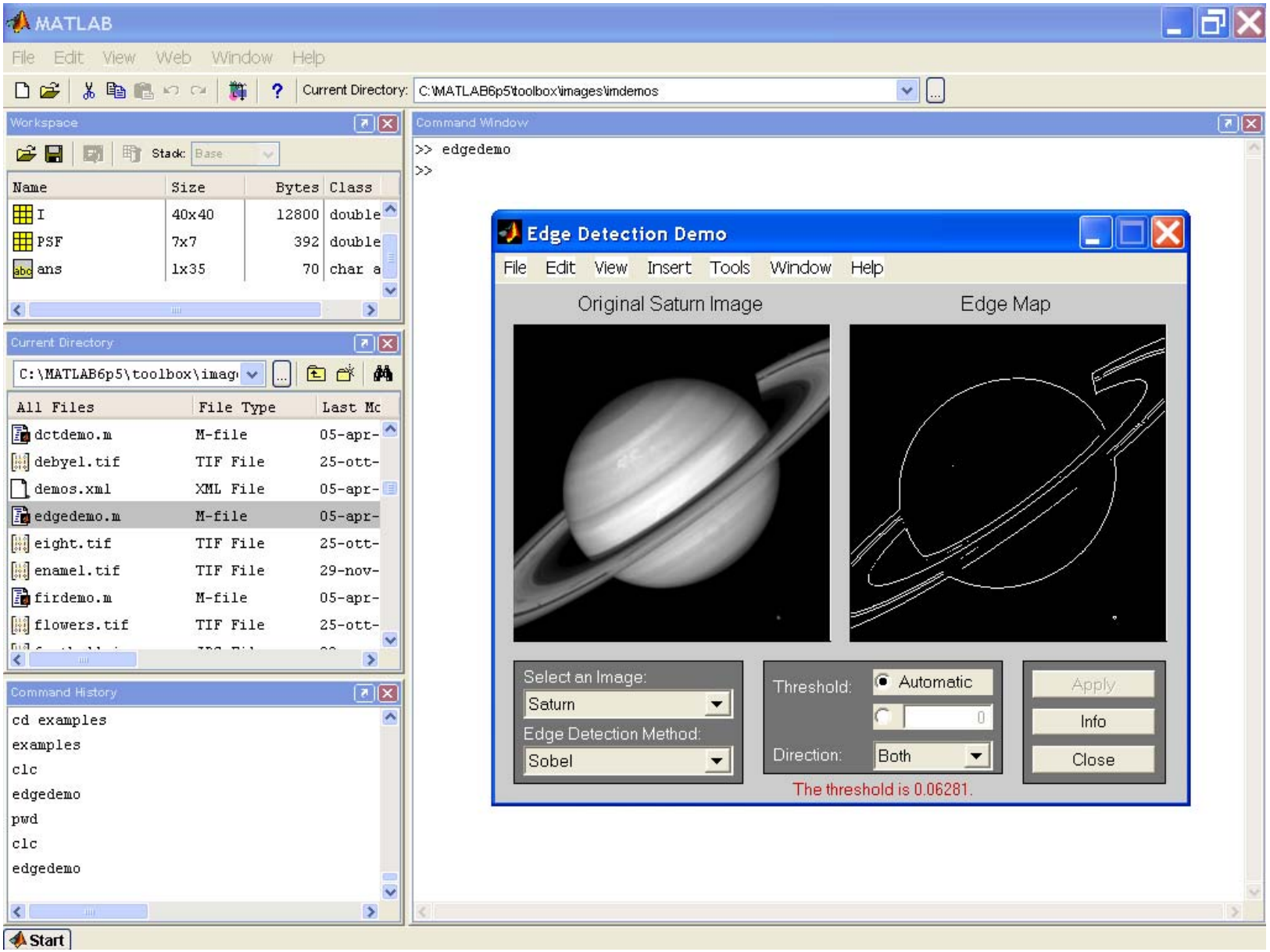
Matlab


MATLAB
File Edit View Web Window Help
Current Directory: C:\MATLAB6p5\work
Workspace
Stack: Base
Name Size Bytes Class
Current Directory
C:\MATLAB6p5\work
All Files File Type Last Mc
acq.m M-file 20-gen-
arg.m M-file 05-feb-
CentralCaseHiD.m M-file 27-gen-
cluster3D.m M-file 27-gen-
compgym.asv ASV File 12-ago-
compgym.m M-file 13-ago-
convarg.m M-file 10-feb-
convdate.m M-file 10-feb-
convval.m M-file 10-feb-
esempio.m M-file 06-feb-
FewPoints.m M-file 27-gen-
hs_err_pid1632.log LOG File 04-feb-
Command History
figure;imshow(I);title('Original Image');
clc
I = imread('cameraman.tif');
figure;imshow(I);title('Original Image');
clc
I = imread('cameraman.tif');
figure;imshow(I);title('Original Image');
Command Window
>> I = imread('cameraman.tif');
figure;imshow(I);title('Original Image');
>>
Figure No. 1
File Edit View Insert Tools Window
Help
Original Image
Start

Matlab


MATLAB
File Edit View Web Window Help
Current Directory: C:\MATLAB6p5\work
Workspace
Stack: Base
Name Size Bytes Class
Command Window
>> I = imread('cameraman.tif');
figure;imshow(I);title('Original Image');
>> PSF = fspecial('gaussian',7,10);
Blurred = imfilter(I,PSF,'symmetric','conv');
figure;imshow(Blurred);title('Blurred Image');
>>
Current Directory
C:\MATLAB6p5\work
All Files File Type Last Mc
acq.m M-file 20-gen-
arg.m M-file 05-feb-
CentralCaseHiD.m M-file 27-gen-
cluster3D.m M-file 27-gen-
compgym.asv ASV File 12-ago-
compgym.m M-file 13-ago-
convarg.m M-file 10-feb-
convdate.m M-file 10-feb-
convval.m M-file 10-feb-
esempio.m M-file 06-feb-
FewPoints.m M-file 27-gen-
hs_err_pid1632.log LOG File 04-feb-
Command History
figure;imshow(I);title('Original Image');
clc
I = imread('cameraman.tif');
figure;imshow(I);title('Original Image');
PSF = fspecial('gaussian',7,10);
Blurred = imfilter(I,PSF,'symmetric','conv'
figure;imshow(Blurred);title('Blurred Image
Figure No. 1
File Edit View Insert Tools Window
Help
Original Image
Figure No. 2
File Edit View Insert Tools Window
Help
Blurred Image
Start

Matlab


MATLAB
File Edit View Web Window Help
Current Directory: C:\MATLAB6p5\toolbox\images\imdemos
Workspace
Stack: Base
Name Size Bytes Class
I 40x40 12800 double
PSF 7x7 392 double
ans 1x35 70 char a
Current Directory
C:\MATLAB6p5\toolbox\imag
All Files File Type Last Mc
dctdemo.m M-file 05-apr-
debyel.tif TIF File 25-ott-
demos.xml XML File 05-apr-
edgedemo.m M-file 05-apr-
eight.tif TIF File 25-ott-
enamel.tif TIF File 29-nov-
firdemo.m M-file 05-apr-
flowers.tif TIF File 25-ott-
Command History
cd examples
examples
clc
edgedemo
pwd
clc
edgedemo
Command Window
>> edgedemo
>>
Edge Detection Demo
File Edit View Insert Tools Window Help
Original Saturn Image
Edge Map
Select an Image:
Saturn
Edge Detection Method:
Sobel
Threshold:
Automatic
0
Direction:
Both
Apply
Info
Close
The threshold is 0.06281.
Start

Matlab

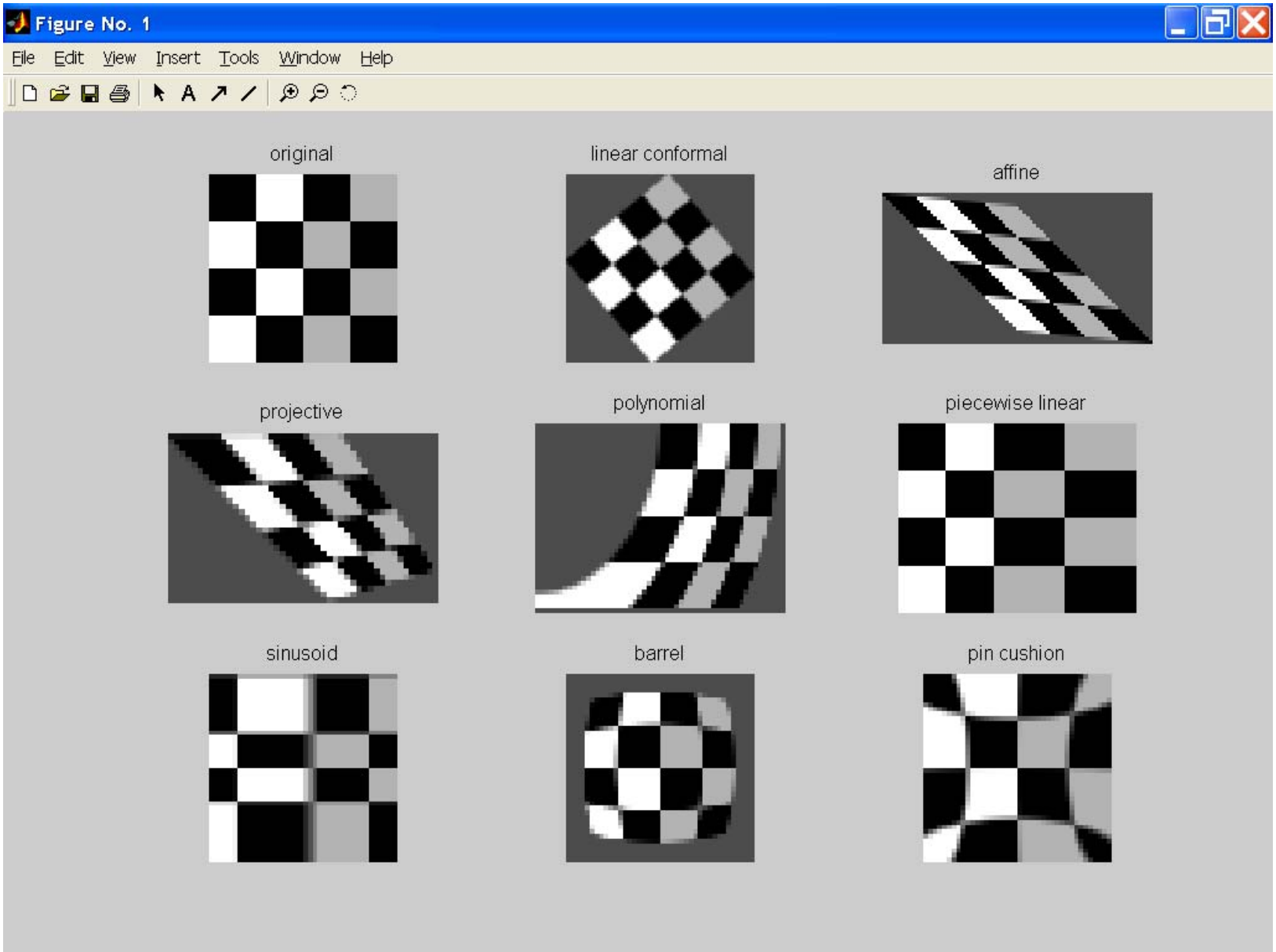
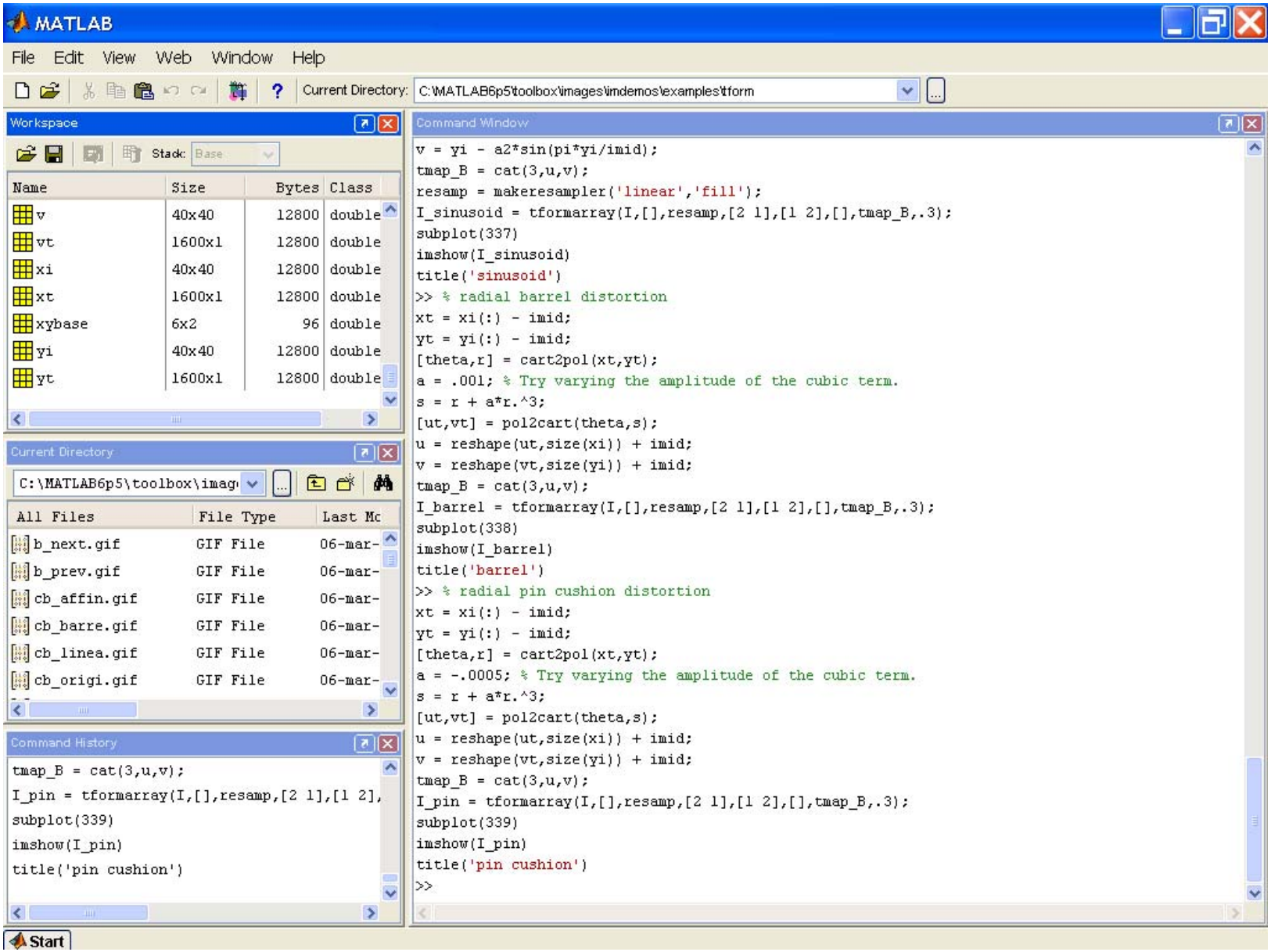
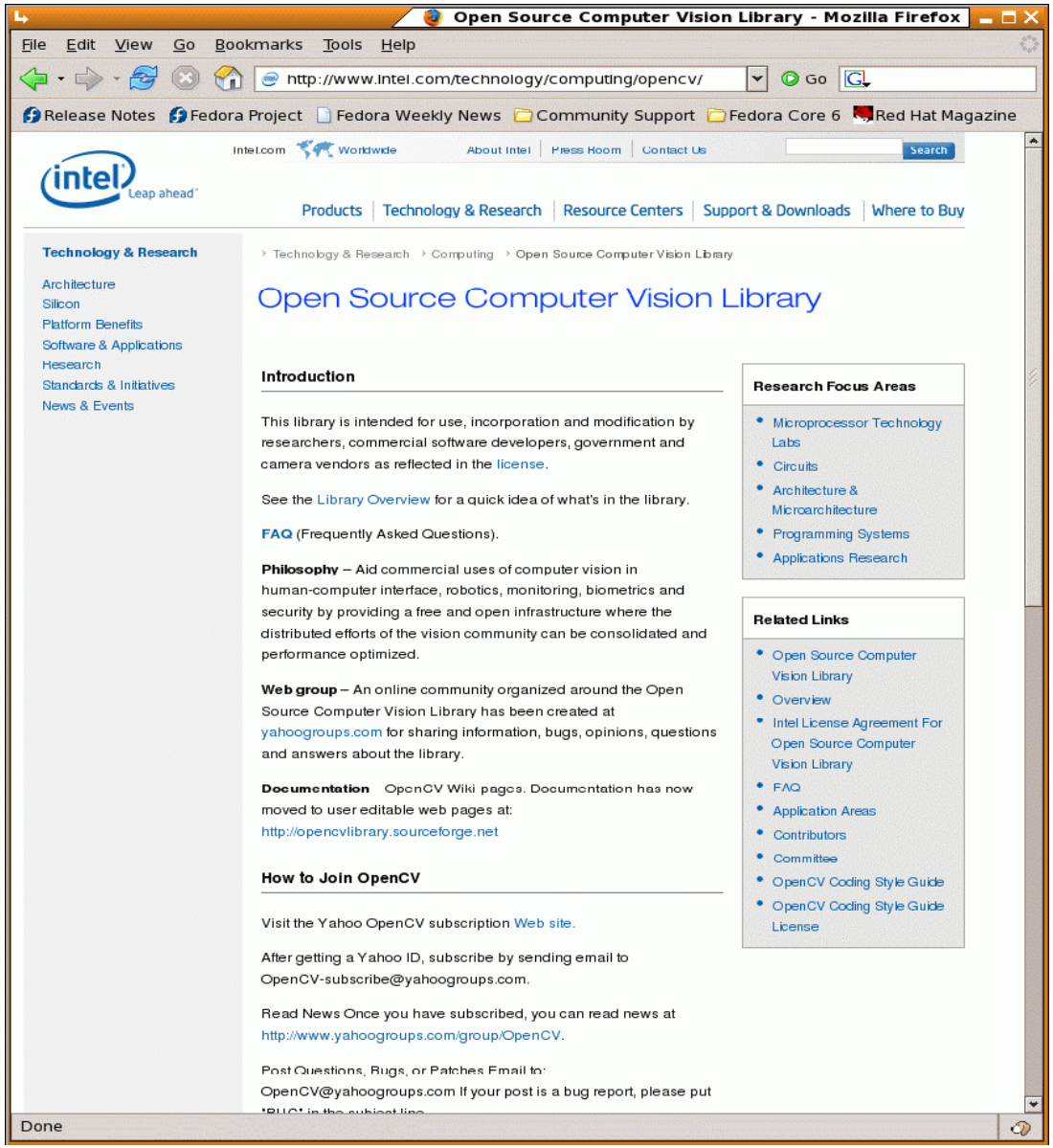


Figure No. 1
File Edit View Insert Tools Window Help
original
linear conformal
affine
projective
polynomial
piecewise linear
sinusoid
barrel
pin cushion

Matlab


MATLAB
File Edit View Web Window Help
Current Directory: C:\MATLAB6p5\toolbox\images\imdemos\examples\tform
Workspace
Stack: Base
Name Size Bytes Class
v 40x40 12800 double
vt 1600x1 12800 double
xi 40x40 12800 double
xt 1600x1 12800 double
xybase 6x2 96 double
yi 40x40 12800 double
yt 1600x1 12800 double
Current Directory
C:\MATLAB6p5\toolbox\imag
All Files File Type Last Mc
b_next.gif GIF File 06-mar-
b_prev.gif GIF File 06-mar-
cb_affin.gif GIF File 06-mar-
cb_barre.gif GIF File 06-mar-
cb_linea.gif GIF File 06-mar-
cb_origi.gif GIF File 06-mar-
Command History
tmap_B = cat(3,u,v);
I_pin = tformarray(I,[],resamp,[2 1],[1 2],
subplot(339)
imshow(I_pin)
title('pin cushion')
Command Window
v = yi - a2*sin(pi*yi/imid);
tmap_B = cat(3,u,v);
resamp = makeresampler('linear','fill');
I_sinusoid = tformarray(I,[],resamp,[2 1],[1 2],[],tmap_B,.3);
subplot(337)
imshow(I_sinusoid)
title('sinusoid')
>> % radial barrel distortion
xt = xi(:) - imid;
yt = yi(:) - imid;
[theta,r] = cart2pol(xt,yt);
a = .001; % Try varying the amplitude of the cubic term.
s = r + a*r.^3;
[ut,vt] = pol2cart(theta,s);
u = reshape(ut,size(xi)) + imid;
v = reshape(vt,size(yi)) + imid;
tmap_B = cat(3,u,v);
I_barrel = tformarray(I,[],resamp,[2 1],[1 2],[],tmap_B,.3);
subplot(338)
imshow(I_barrel)
title('barrel')
>> % radial pin cushion distortion
xt = xi(:) - imid;
yt = yi(:) - imid;
[theta,r] = cart2pol(xt,yt);
a = -.0005; % Try varying the amplitude of the cubic term.
s = r + a*r.^3;
[ut,vt] = pol2cart(theta,s);
u = reshape(ut,size(xi)) + imid;
v = reshape(vt,size(yi)) + imid;
tmap_B = cat(3,u,v);
I_pin = tformarray(I,[],resamp,[2 1],[1 2],[],tmap_B,.3);
subplot(339)
imshow(I_pin)
title('pin cushion')
>>
Start

OpenCV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This library is intended for use, incorporation and modification by researchers, commercial software developers, government and camera vendors as reflected in the license.
See the Library Overview for a quick idea of what's in the library.
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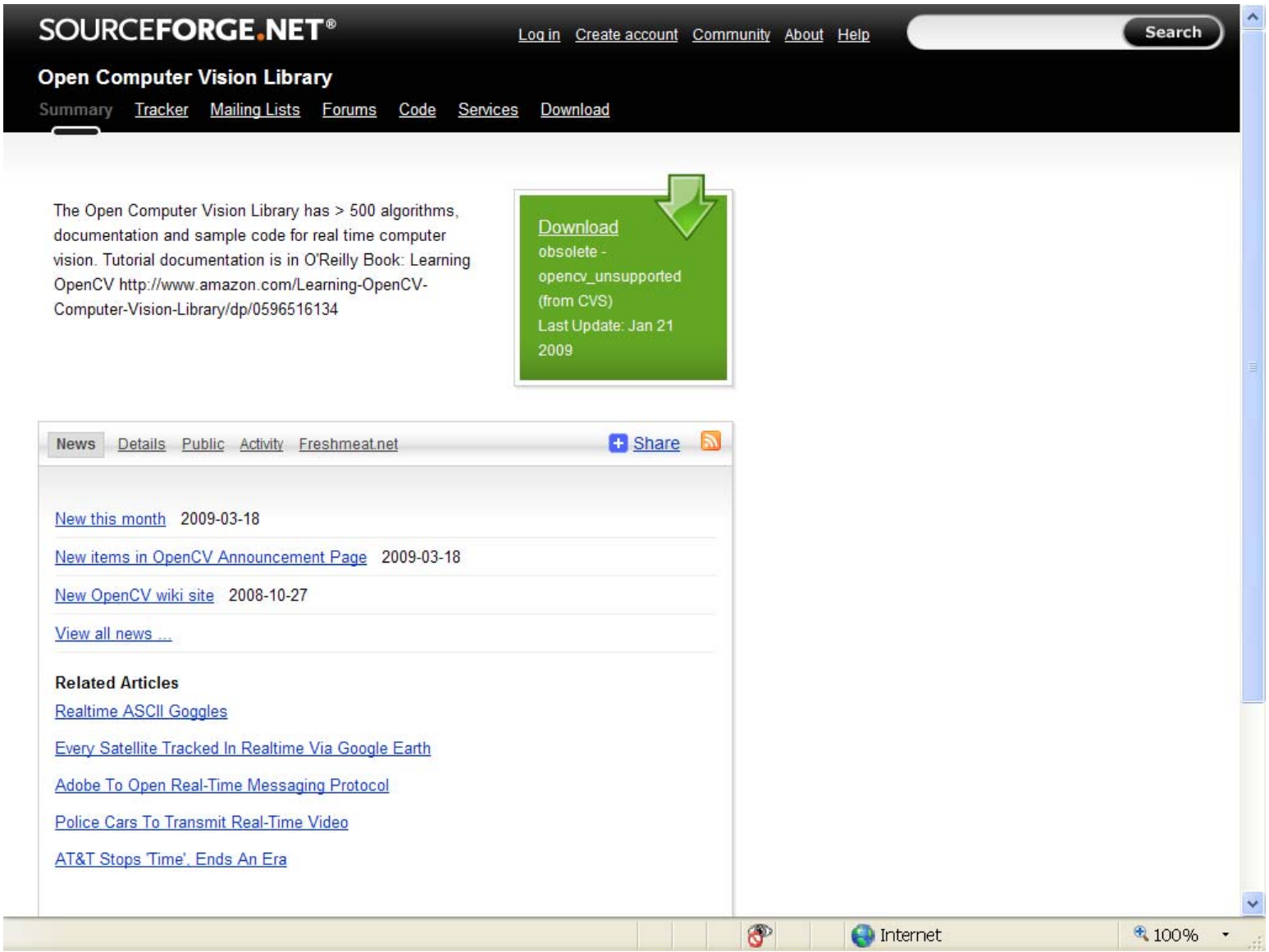
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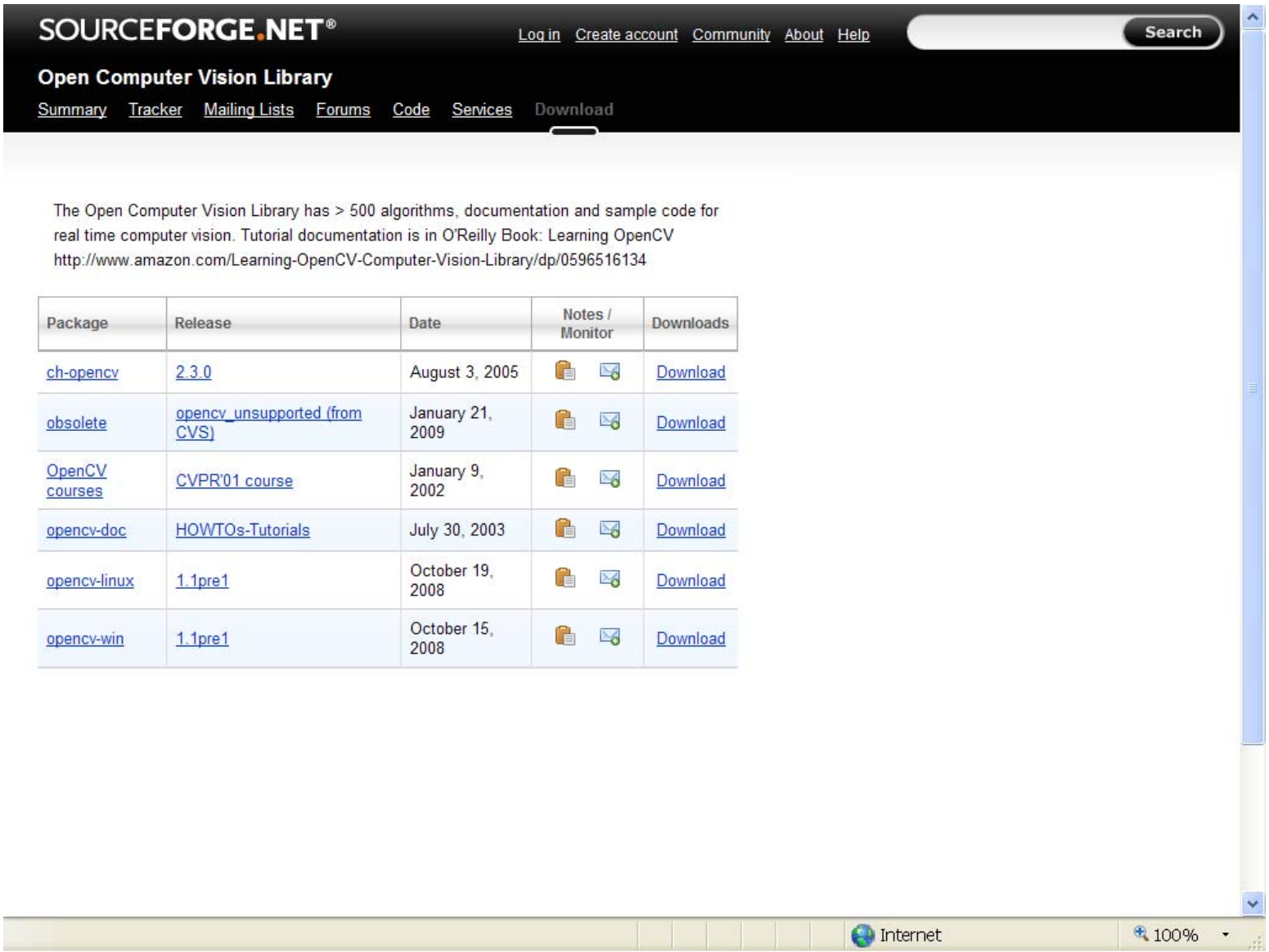
OpenCV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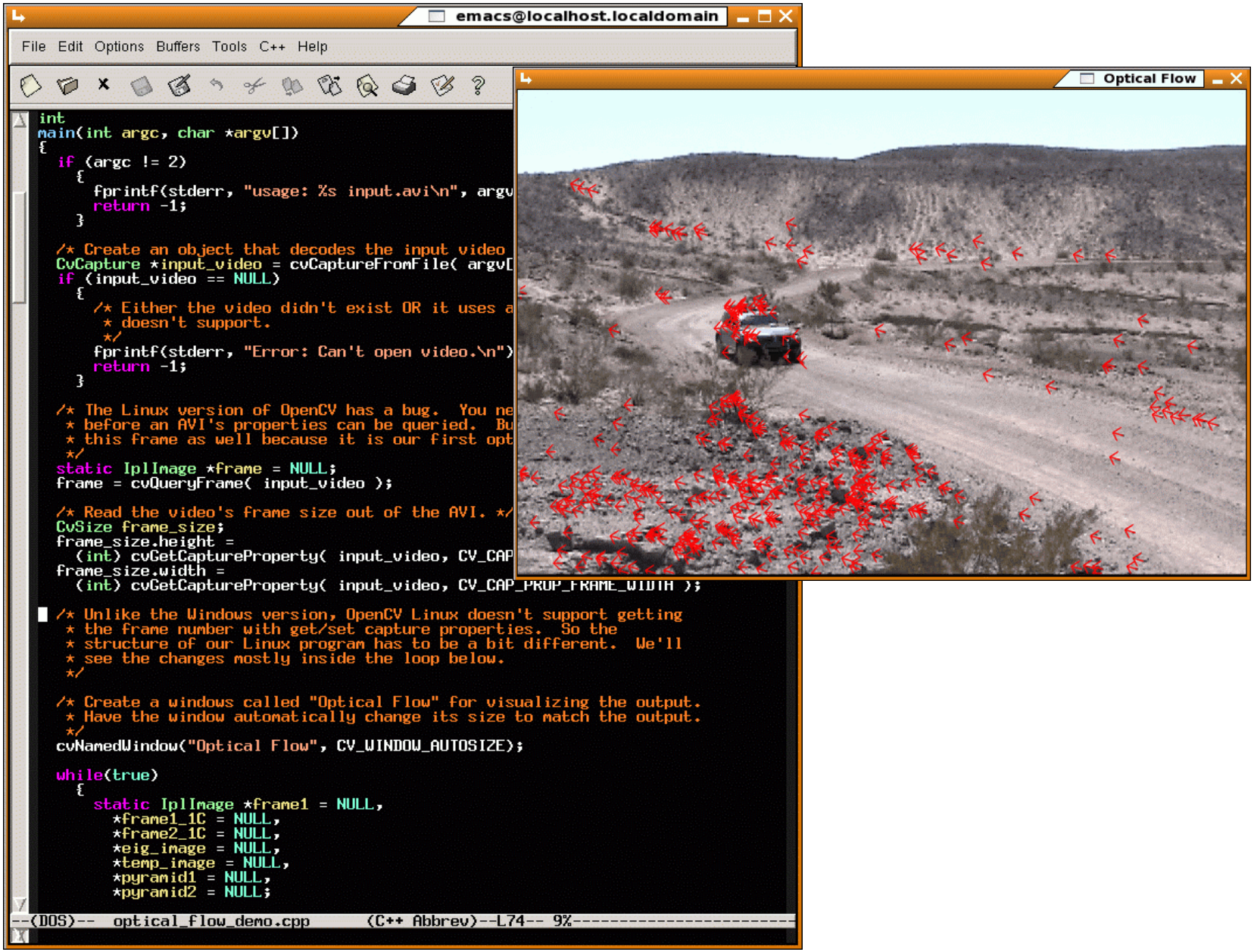
OpenCV

```
#include <iostream.h>
#include <stdlib.h>
#include <stdio.h>
#include <assert.h>
#include <math.h>
#include <signal.h>
#include <opencv/cv.h>
#include <opencv/highgui.h>


int
main()
{

  CvvImage im;                    // create image variable
  im.Load("bridge.jpg");          // load image from file system
  cvNamedWindow("main", 0);       // create display window
  im.Show("main");                // show image in window

  CvvImage imBW;                  // create image variable
  imBW.Create(im.Width(), im.Height(), 8);      // allocate
  cvCvtColor(im.GetImage(), imBW.GetImage(),CV_BGR2GRAY); // BW

  cvNamedWindow("bw", 0);         // create display window
  imBW.Show("bw");                // show image in window

  CvvImage imCanny;               // create image variable
  imCanny.Create(imBW.Width(), imBW.Height(), 8); // allocate
  cvCanny(imBW.GetImage(), imCanny.GetImage(), 25, 75, 3); // Canny edges

  cvNamedWindow("canny", 0);      // create display window
  imCanny.Show("canny");          // show image in window
  imCanny.Save("canny.jpg");              // save the result

  for (;;)
    cvWaitKey(0);                  // (necessary for resizing+displaying window)
}
```

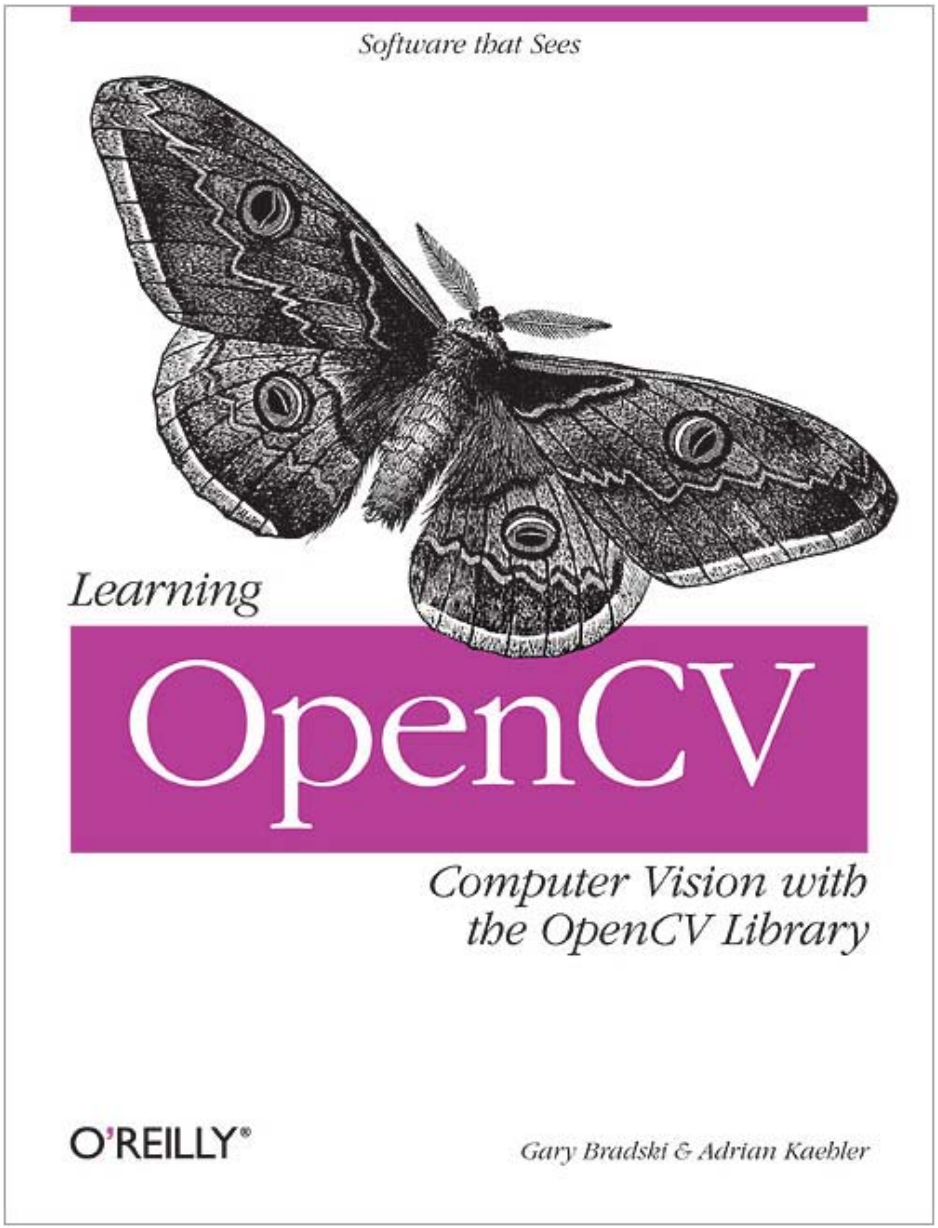
OpenCV

```
$ g++ -c test.cc -I/usr/local/include/opencv -Wno-deprecated -Wall
$ g++ -g test.o -L/usr/local/lib -lcv -lhighgui -o test
```

OpenCV


emacs@localhost.localdomain
File Edit Options Buffers Tools C++ Help
int
main(int argc, char *argv[])
{
if (argc != 2)
{
fprintf(stderr, "usage: %s input.avi\n", argv
return -1;
}
/* Create an object that decodes the input video
CvCapture *input_video = cvCaptureFromFile(argv[
if (input_video == NULL)
{
/* Either the video didn't exist OR it uses a
* doesn't support.
*/
fprintf(stderr, "Error: Can't open video.\n")
return -1;
}
/* The Linux version of OpenCV has a bug. You ne
* before an AVI's properties can be queried. Bu
* this frame as well because it is our first opt
*/
static IplImage *frame = NULL;
frame = cvQueryFrame(input_video);
/* Read the video's frame size out of the AVI. */
CvSize frame_size;
frame_size.height =
(int) cvGetCaptureProperty(input_video, CV_CAP
frame_size.width =
(int) cvGetCaptureProperty(input_video, CV_CAP_PROP_FRAME_WIDTH);
/* Unlike the Windows version, OpenCV Linux doesn't support getting
* the frame number with get/set capture properties. So the
* structure of our Linux program has to be a bit different. We'll
* see the changes mostly inside the loop below.
*/
/* Create a windows called "Optical Flow" for visualizing the output.
* Have the window automatically change its size to match the output.
*/
cvNamedWindow("Optical Flow", CV_WINDOW_AUTOSIZE);
while(true)
{
static IplImage *frame1 = NULL,
*frame1_1C = NULL,
*frame2_1C = NULL,
*eig_image = NULL,
*temp_image = NULL,
*pyramid1 = NULL,
*pyramid2 = NULL;
--(DOS)-- optical_flow_demo.cpp (C++ Abbrev)--L74-- 9%
Optical Flow

OpenCV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Matlab vs OpenCV

- Matlab
  - Estremamente facile da usare
  - Interprete + Compilatore
  - Grafica avanzata
  - Installazione non immediata su Linux
- OpenCV
  - Altamente efficiente
  - Funzioni più avanzate
  - Pre-installato su alcune distribuzioni di Linux
  - Porting recente su GPU

Riferimenti bibliografici

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