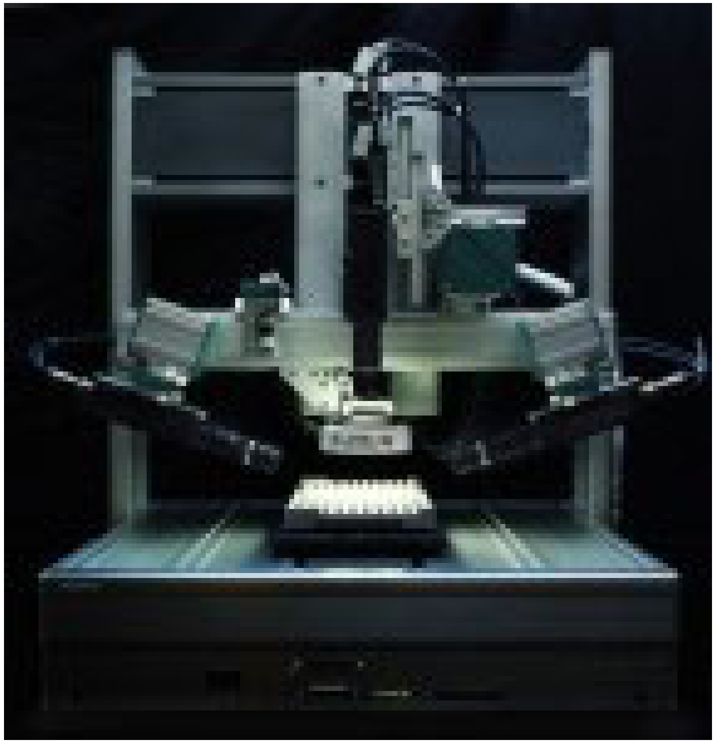
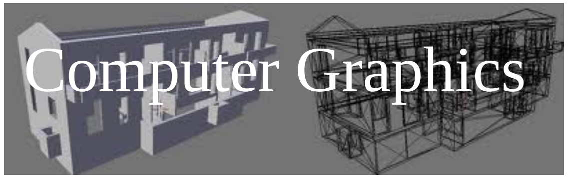
Robot vision

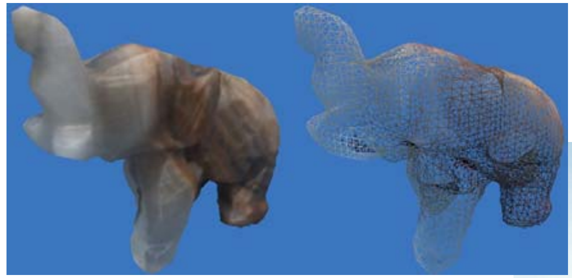


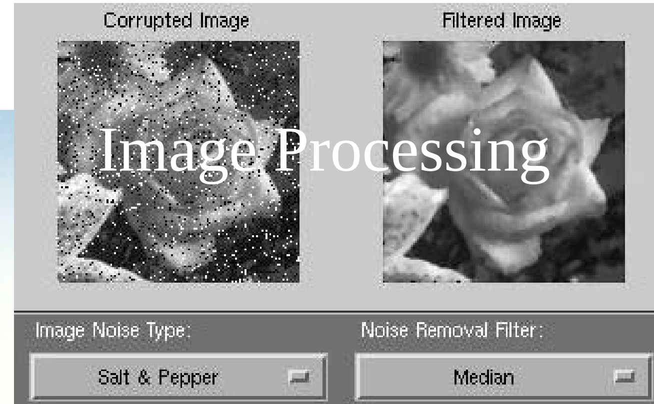
Martin
Jagersand

Addt' slides
by D. Pugh
N. Krouglic

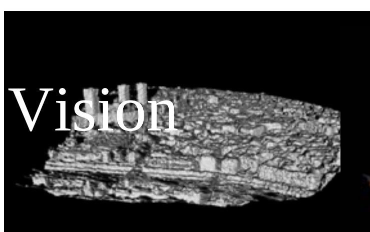
What is Computer Vision?

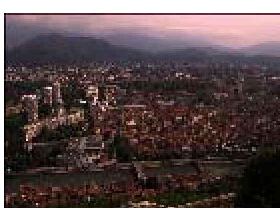




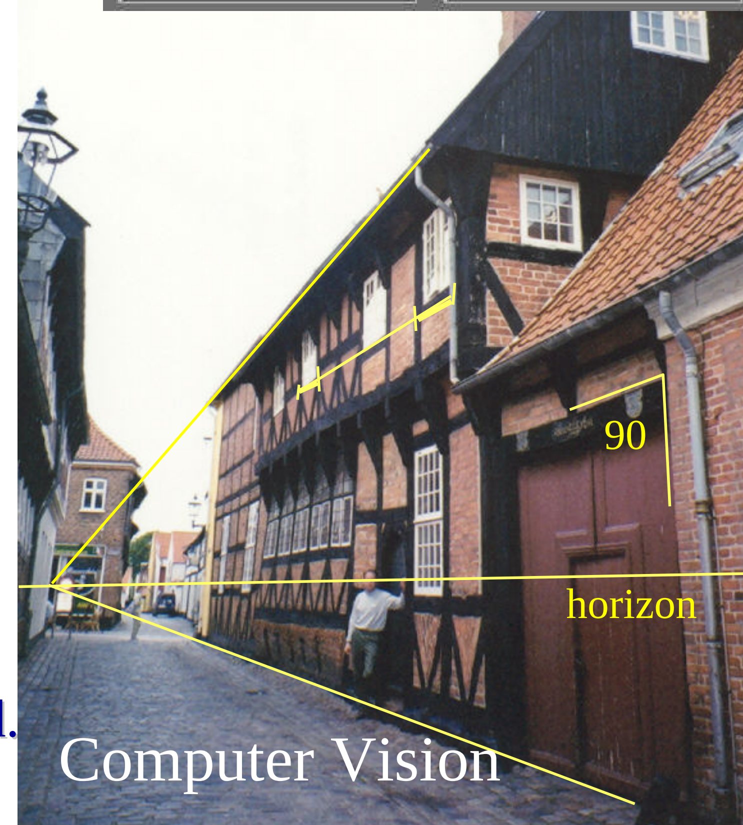


- Three Related fields
  - Image Processing: Changes 2D images into other 2D images
  - Computer Graphics: Takes 3D models, renders 2D images
  - Computer vision: Extracts scene information from 2D images and video
    - e.g. Geometry, "Where" something is in 3D,
    - Objects "What" something is"
- What information is in a 2D image?
- What information do we need for 3D analysis?



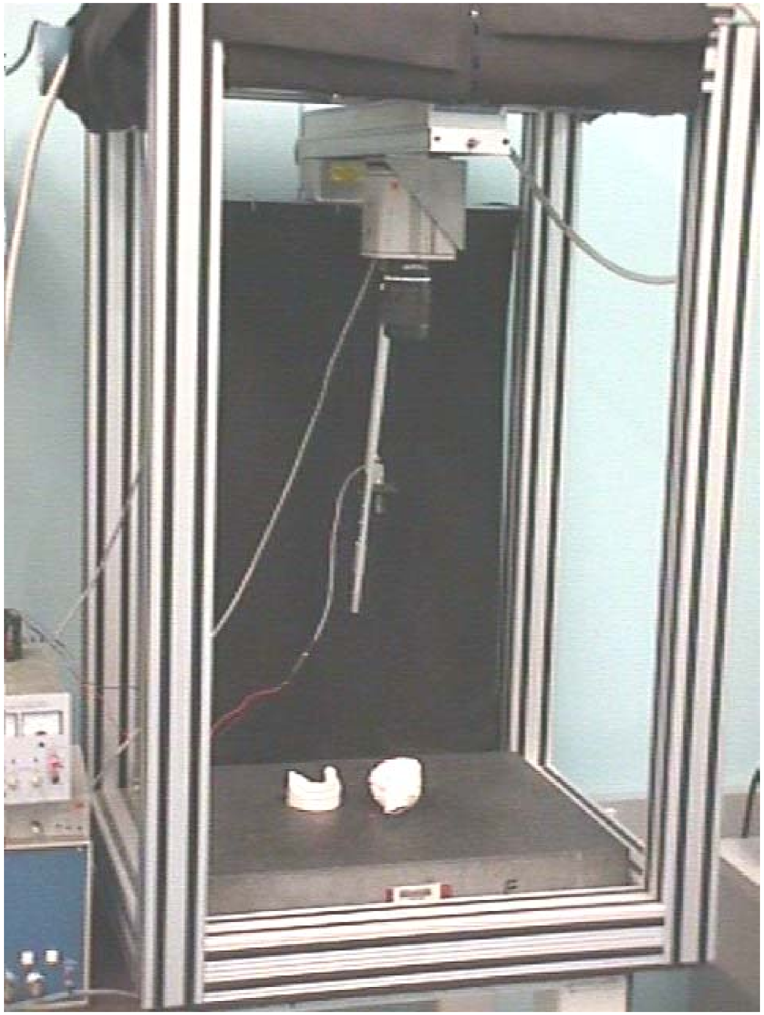


hard. Only special cases can be solved.

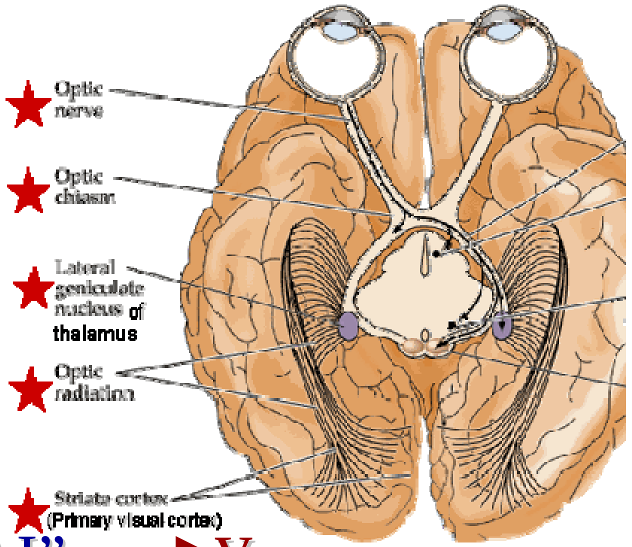


Machine Vision

- 3D Camera vision in general environments hard
- Machine vision:
  - Use engineered environment
  - Use 2D when possible
  - Special markers/LED
  - Can buy working system!
- Photogrammetry:
  - Outdoors
  - 3D surveying using cameras



Vision



- Full: Human vision
  - We don’t know how it works in detail
- Limited vision: Machines, Robots, “AI”

What is the most basic useful information we can get from a camera?

1. Location of a dot (LED/Marker) [u,v] = f(I)
2. Segmentation of object pixels

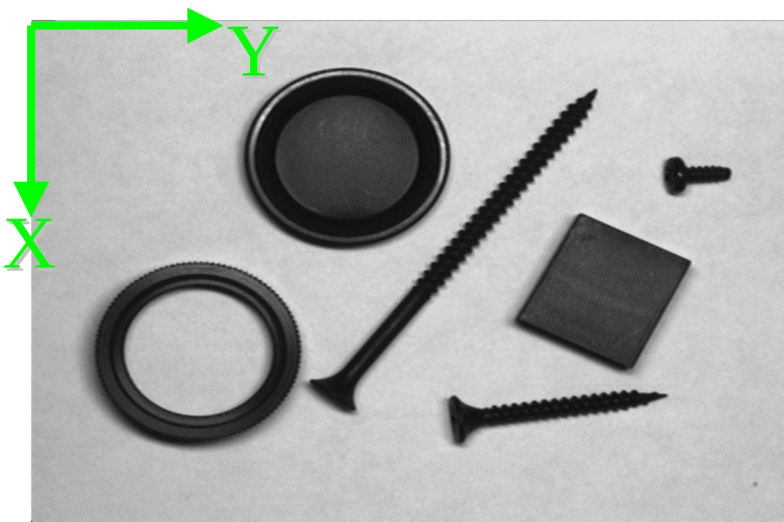
All of these are 2D image plane measurements!

What is the best camera location?

Usually overhead pointing straight down

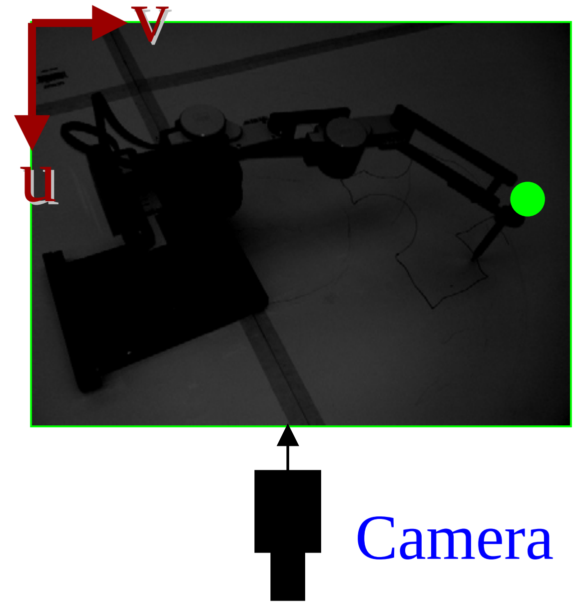
Adjust cam position so pixel [u,v] = s[X,Y].

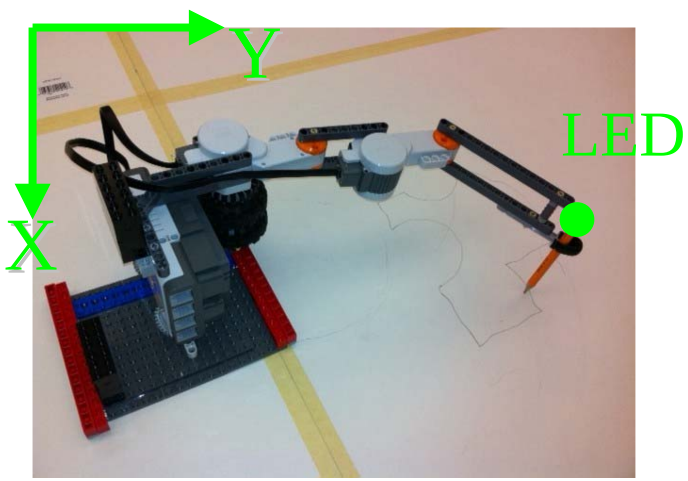
Pixel coordinates are scaled world coord



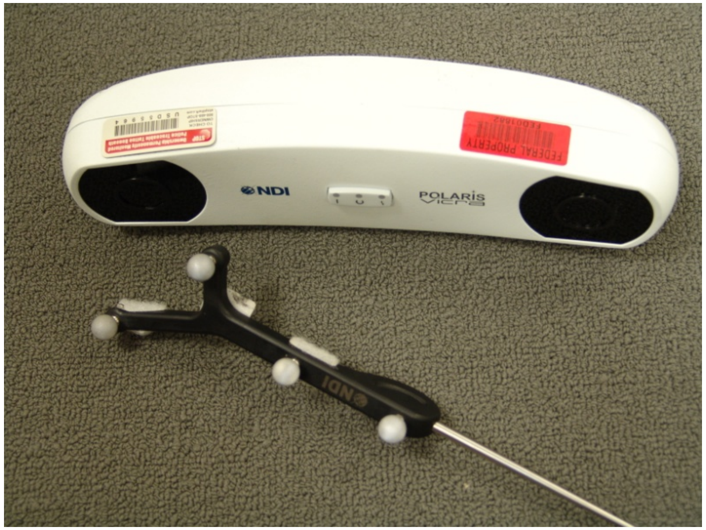
Tracking LED special markers

- Put camera overhead pointing straight down on worktable.
  - Adjust cam position so pixel [u,v] = s[X,Y]. Pixel coordinates are scaled world coord
  - Lower brightness so LED brighterest
- Put LED on robot end-effector
- Detection algorithm:
  - Threshold brightest pixels I(u,v)>200
  - Find centroid [u,v] of max pixels
- Variations:
  - Blinking LED can enhance detection in ambient light.
  - Different color LED's can be detected separately from R,G,B color video.

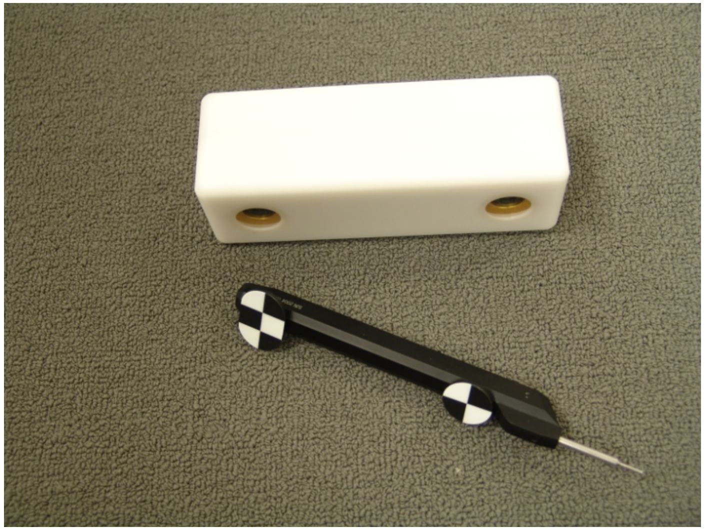




Commercial tracking systems



Polaris Vicra infra-red system
(Northern Digitial Inc.)



MicronTracker visible light system
(Claron Technology Inc.)

Commercial tracking system

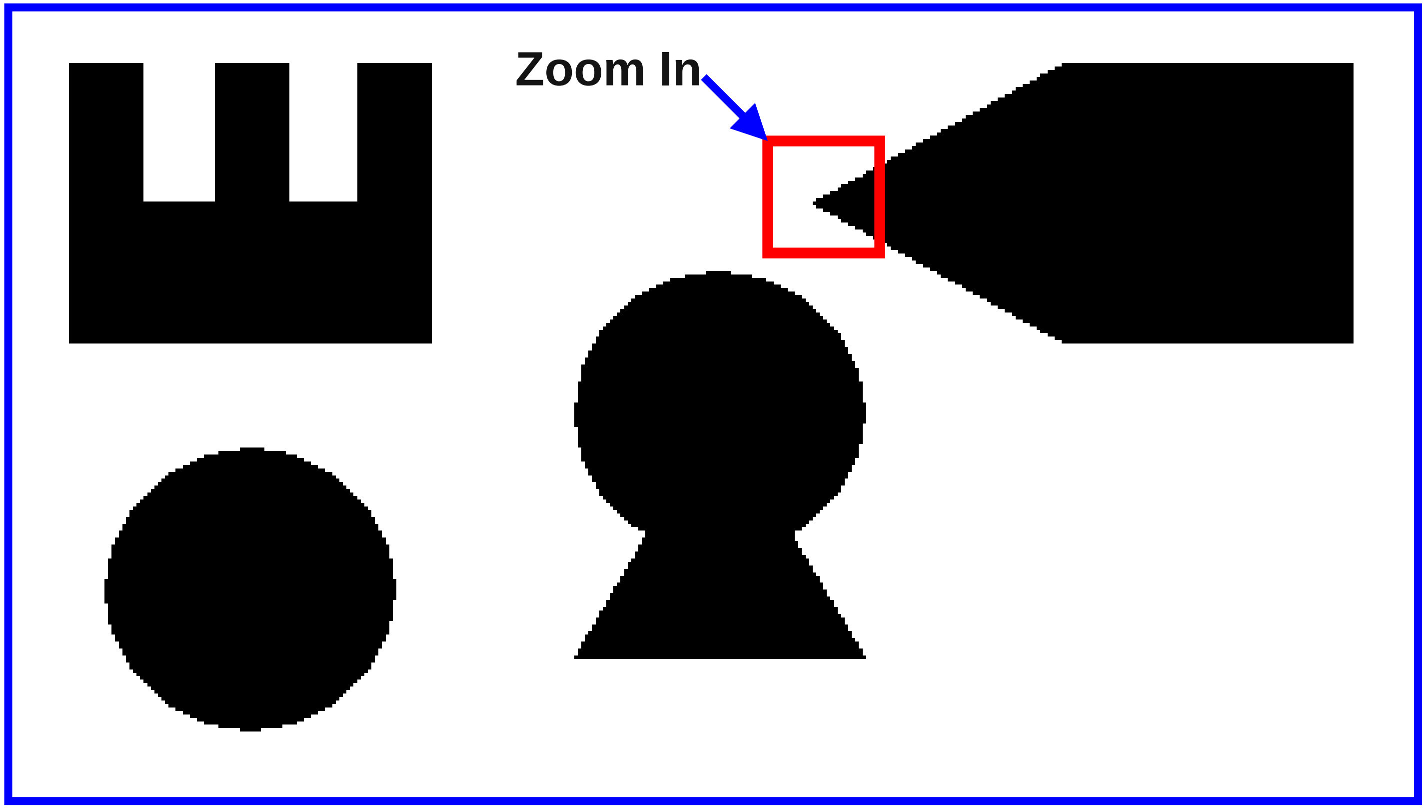
Images acquired by the Polaris Vicra infra-red stereo system:

left image

right image

IMAGE SEGMENTATION

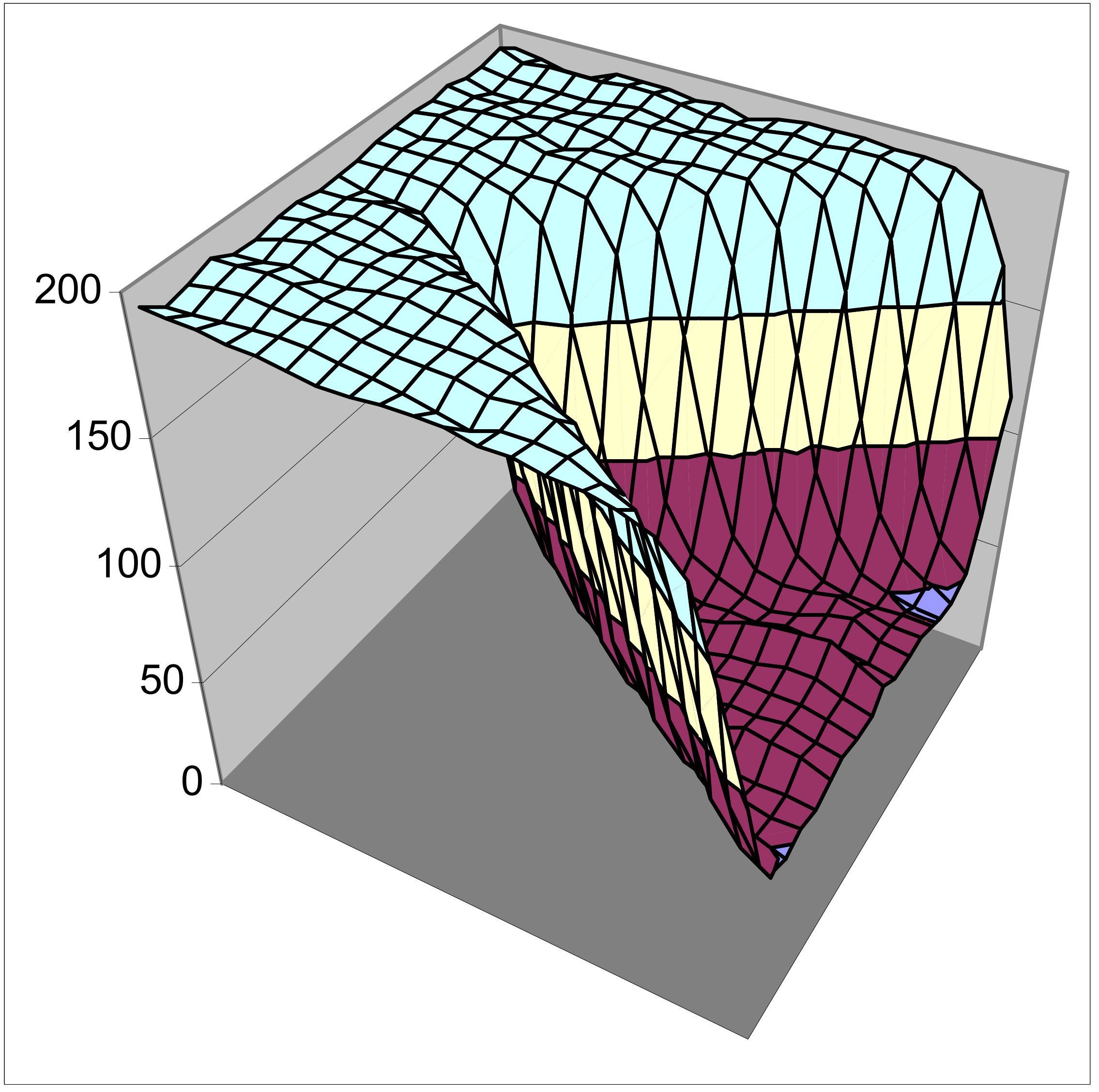
- How many *"objects"* are there in the image below?
- Assuming the answer is "4", what exactly defines an object?



8 BIT GRAYSCALE IMAGE

197	197	197	195	195	194	193	193	194	194	194	193	193	191	190	188	185	174	142	101
191	192	193	194	195	195	194	193	191	189	187	190	191	190	186	181	158	119	86	66
193	195	196	196	195	196	195	194	194	193	191	192	191	187	175	145	105	73	58	51
196	197	197	197	196	195	194	193	193	193	192	188	183	161	121	86	67	59	52	48
192	193	194	193	194	195	196	195	195	192	189	176	144	102	72	59	56	53	51	52
192	194	196	195	195	195	195	196	195	189	167	124	87	68	57	53	52	51	51	50
194	195	195	194	194	195	194	193	184	155	107	73	60	55	53	55	60	60	58	54
194	193	194	194	191	191	188	172	134	94	68	56	51	51	53	57	57	58	56	54
193	193	194	195	193	184	156	112	77	60	53	52	51	53	56	58	58	58	56	53
192	190	189	188	178	140	92	68	57	52	50	50	52	53	56	57	60	60	58	54
193	193	194	193	189	170	125	85	63	55	54	54	55	58	63	66	67	68	64	59
194	195	195	195	193	191	183	153	107	76	60	55	54	54	55	57	57	56	55	53
195	194	195	196	193	192	192	190	173	123	83	63	57	53	51	54	59	62	57	54
196	197	196	195	197	195	195	194	192	179	143	99	69	58	56	56	59	58	55	54
195	195	196	196	194	192	194	194	194	194	190	168	117	78	61	54	51	51	52	52
196	195	195	193	194	195	194	191	191	192	193	193	179	134	90	66	53	50	47	46
194	192	192	193	193	194	195	195	195	195	195	195	194	187	156	110	74	57	51	46
194	193	192	192	192	194	194	193	192	193	193	192	192	192	189	173	129	84	62	52
196	194	194	195	195	196	195	194	193	193	193	194	193	195	194	192	185	150	99	69
192	190	189	189	192	192	192	191	192	190	192	194	194	194	193	192	192	187	163	114

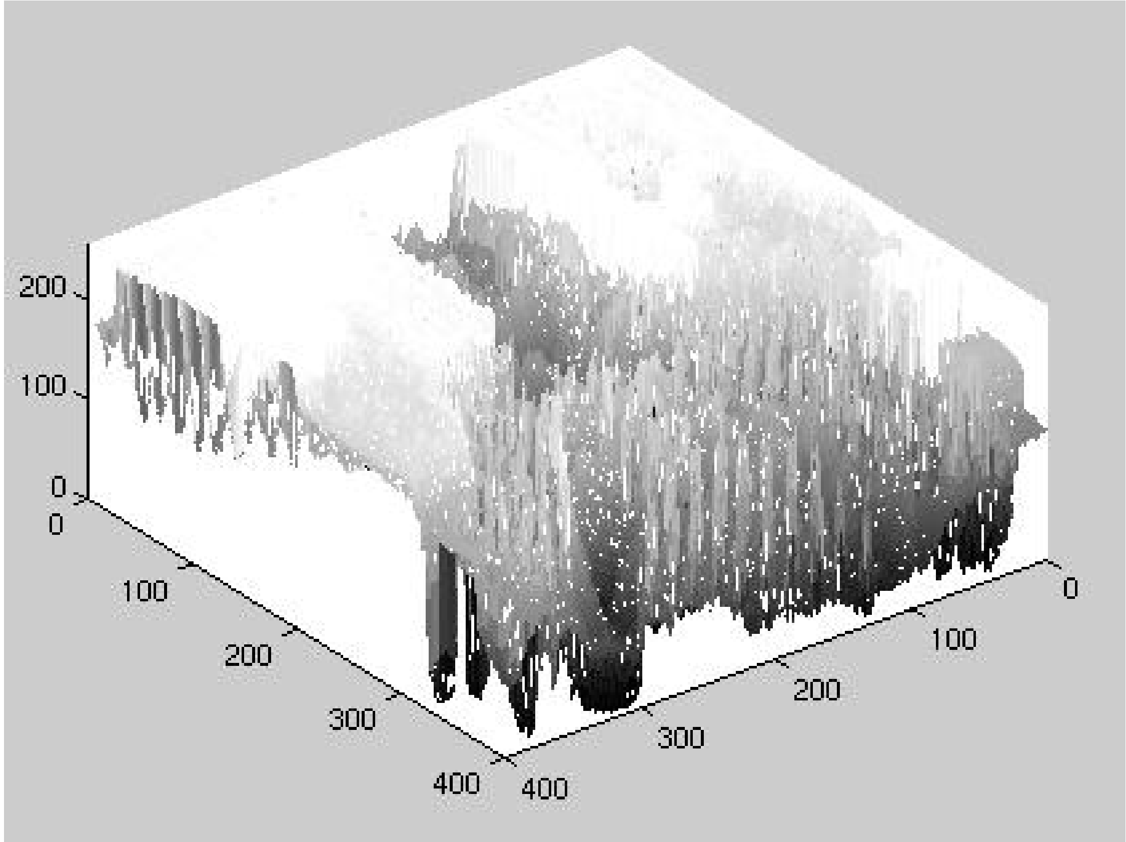
8 BIT GRAYSCALE IMAGE



Compare: Natural image

What is this?

207	200	194	194	203	130	105	095	107	153	192	196	190	186	175
242	194	222	254	255	124	074	082	072	076	208	206	202	194	185
254	170	204	255	248	122	153	135	111	081	252	253	233	232	250
255	172	201	255	249	123	092	040	094	106	255	253	239	150	254
255	197	192	255	248	133	024	027	076	032	250	255	255	181	255
253	210	190	239	250	089	092	149	128	013	254	254	253	229	255
252	238	180	218	251	106	116	181	140	024	250	255	255	255	200
248	248	169	227	252	111	066	118	061	021	252	251	255	255	142
253	255	171	254	253	142	037	132	006	017	253	253	255	254	201
253	250	170	255	253	139	134	127	156	078	255	253	253	254	237
254	228	169	213	235	146	123	096	090	130	230	250	253	254	254
252	244	140	215	245	125	055	043	081	077	252	234	253	253	253
254	250	169	211	235	117	108	093	119	078	246	249	235	225	255
254	234	167	212	217	110	070	049	098	074	244	246	239	207	254
255	219	170	238	253	113	130	109	063	075	243	235	233	252	252
255	221	179	248	227	111	083	041	061	083	240	249	243	232	253
221	217	180	213	243	109	079	048	100	045	246	249	244	221	210
236	216	178	208	230	156	077	062	110	088	244	249	230	220	221
229	224	183	211	132	052	087	062	124	085	135	246	236	220	214
230	223	185	185	112	079	008	124	158	125	119	119	232	225	232
221	215	194	100	154	071	008	031	097	010	093	098	148	229	216
223	217	132	046	072	076	056	048	013	182	073	076	083	215	219
224	216	041	102	090	162	079	111	118	164	083	170	065	221	219
215	222	046	111	077	075	060	046	069	032	179	068	157	224	226
219	216	092	045	074	143	013	171	159	072	087	065	143	217	222
222	224	070	041	074	131	085	150	112	140	139	154	055	231	218
226	232	118	109	041	165	130	105	097	175	078	081	067	064	174
253	254	079	072	116	089	020	068	103	074	031	130	106	052	161
047	034	090	045	145	027	135	109	082	082	048	113	087	061	157
193	192	057	038	051	092	018	062	110	052	060	084	066	071	154
191	192	043	153	052	030	078	061	062	054	046	049	054	078	158
184	181	066	019	043	038	046	083	057	050	145	048	035	087	158
138	074	030	082	030	038	076	041	141	046	045	040	009	063	149
135	016	057	071	035	025	040	062	030	084	130	043	059	113	151



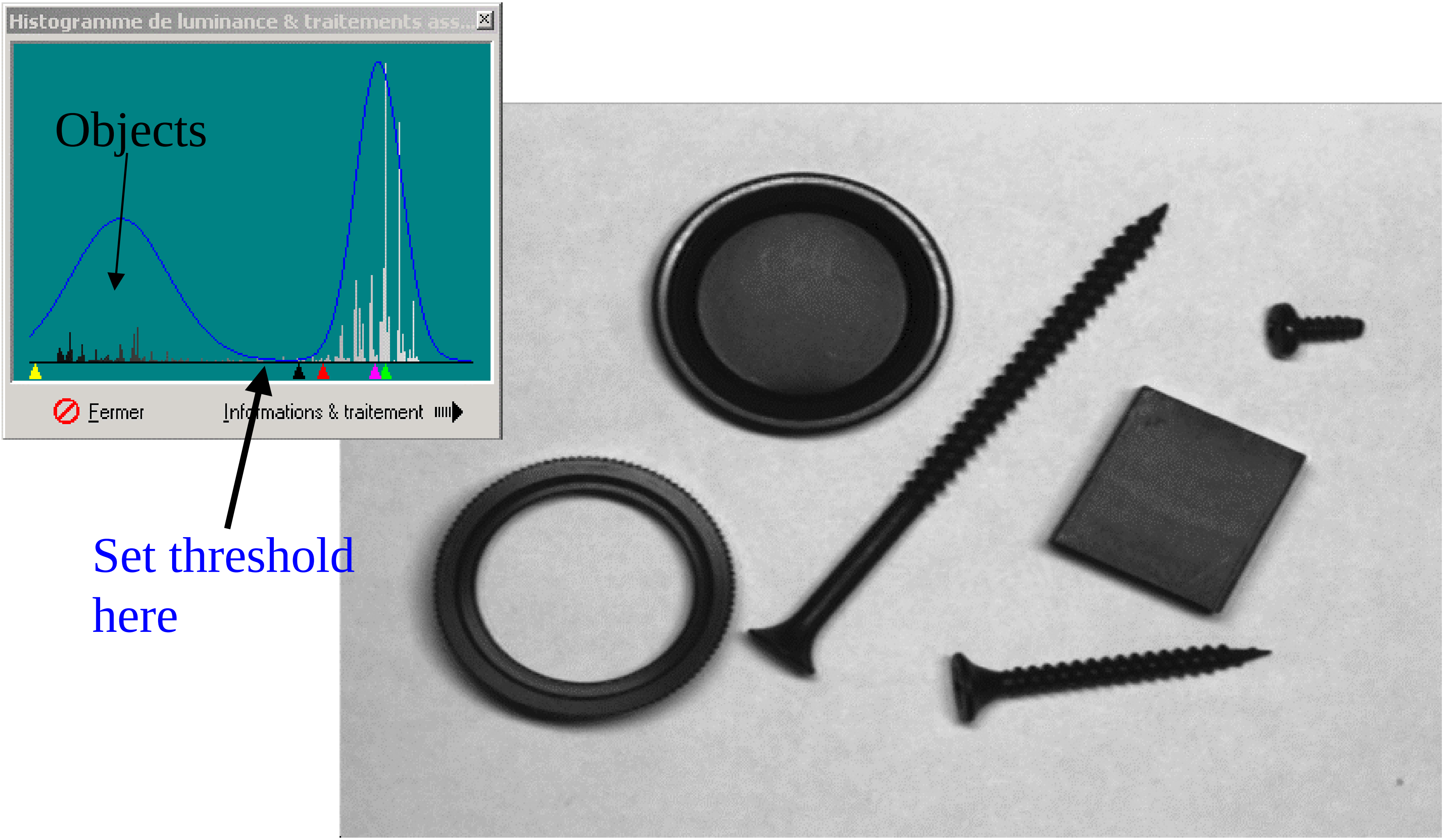
Compare: Natural image

020	067	073	058	055	076	069	050	074	064	065	066	066	059	023
047	109	107	118	107	115	110	120	120	124	120	128	124	132	131
047	125	130	130	122	121	117	142	131	133	134	141	149	144	135
051	139	143	139	147	134	149	069	127	144	139	144	150	161	149
054	136	161	148	147	158	055	052	034	030	158	156	165	163	156
043	144	165	159	154	171	224	191	047	030	171	165	175	164	163
025	161	174	172	167	049	200	193	112	028	120	169	173	177	173
011	091	101	105	177	039	078	060	041	026	073	102	167	208	121
011	091	094	066	094	033	199	184	139	024	060	094	125	152	134
009	068	072	072	065	031	151	171	075	028	035	072	083	109	063
013	068	074	059	057	037	161	129	062	028	035	071	072	078	056
012	042	063	055	072	033	020	067	031	022	027	082	070	073	060
011	037	064	094	091	026	025	080	066	026	023	071	070	080	060
011	060	077	082	037	023	024	147	140	038	023	037	043	076	037
013	049	076	059	032	028	174	197	182	060	021	021	121	101	062
013	059	111	072	020	078	200	211	182	061	069	059	043	086	106
007	053	057	092	023	105	189	230	210	084	034	021	017	033	091
011	061	072	018	027	054	069	068	062	023	045	011	016	042	044
014	041	047	025	018	040	065	039	024	021	036	041	013	030	022
013	093	106	017	019	027	030	042	012	021	043	013	014	020	027
019	040	029	023	016	024	015	026	011	010	026	017	012	013	014
022	042	030	040	019	015	016	011	012	009	008	012	009	017	019
022	026	018	030	020	012	017	010	008	011	007	015	008	016	034
019	018	048	029	012	054	012	008	008	009	008	012	007	016	005
022	015	057	043	126	135	122	006	005	008	007	019	010	011	008
018	008	009	019	023	093	109	128	063	052	031	010	012	009	006
017	010	010	007	067	054	106	116	067	056	011	028	005	009	006
015	010	012	014	062	076	057	055	019	024	020	006	005	013	004
016	010	008	011	039	025	020	016	011	007	008	007	006	010	003
015	009	010	010	012	011	014	009	008	007	007	005	005	008	002
014	007	008	011	007	012	010	009	007	008	007	005	005	007	003
020	011	015	019	013	017	017	013	019	013	012	013	011	009	005
020	067	073	058	055	076	069	050	074	064	065	066	066	059	023
025	161	174	172	167	049	200	193	112	028	120	169	173	177	173

GRAY LEVEL THRESHOLDING

- Many images consist of two regions that occupy different gray level ranges.
- Such images are characterized by a *bimodal image histogram.*
- An *image histogram* is a function **h** defined on the set of gray levels in a given image.
- The value **h(k)** is given by the number of pixels in the image having image intensity **k**.

GRAY LEVEL THRESHOLDING



BINARY IMAGE

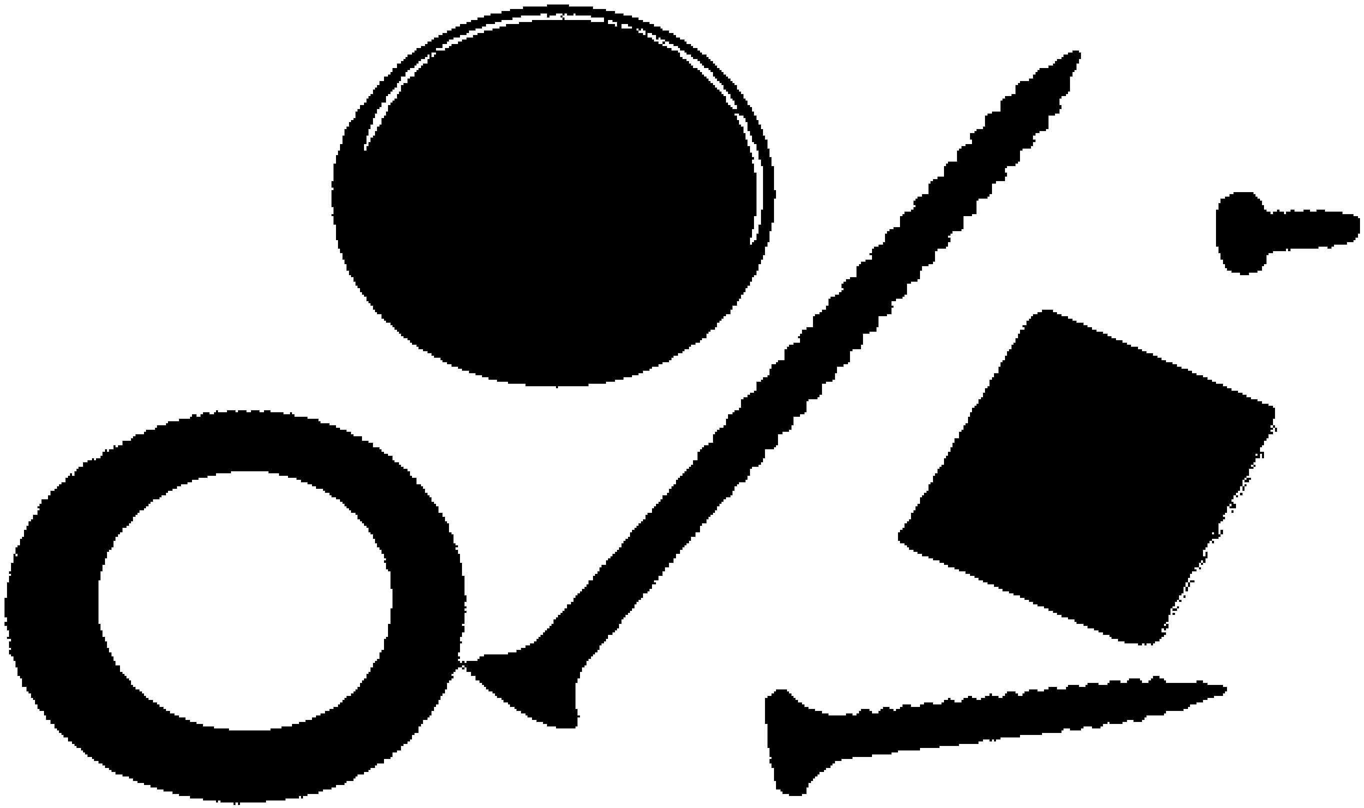


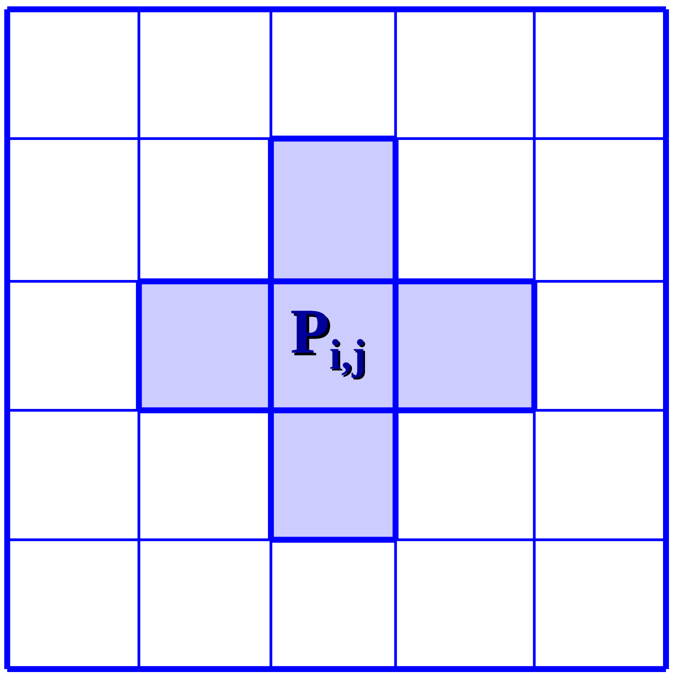
IMAGE SEGMENTATION – CONNECTED COMPONENT LABELING

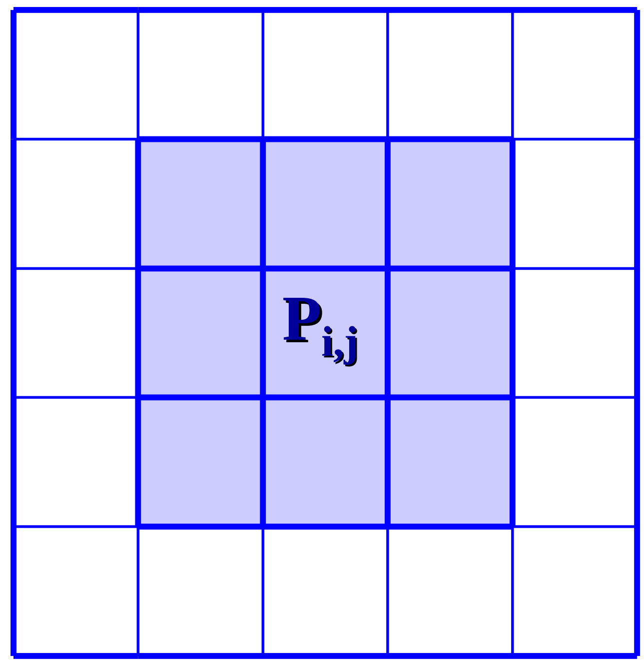
- Segmentation can be viewed as a process of *pixel classification*; the image is segmented into *objects* or *regions* by assigning individual pixels to classes.
- *Connected Component Labeling* assigns pixels to specific classes by verifying if an adjoining pixel (i.e., *neighboring pixel*) already belongs to that class.
- There are two “standard” definitions of pixel connectivity: 4 neighbor connectivity and 8 neighbor connectivity.

IMAGE SEGMENTATION – CONNECTED COMPONENT LABELING

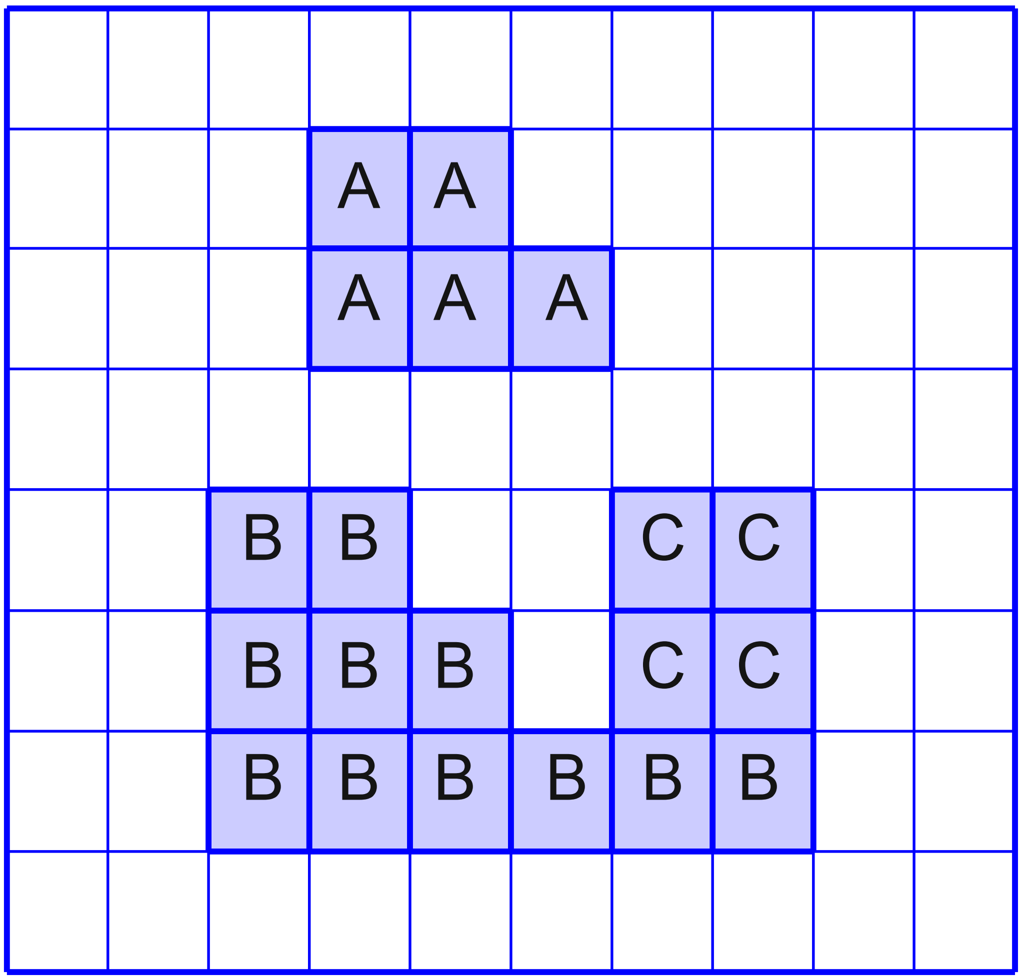
4 Neighbor Connectivity

8 Neighbor Connectivity





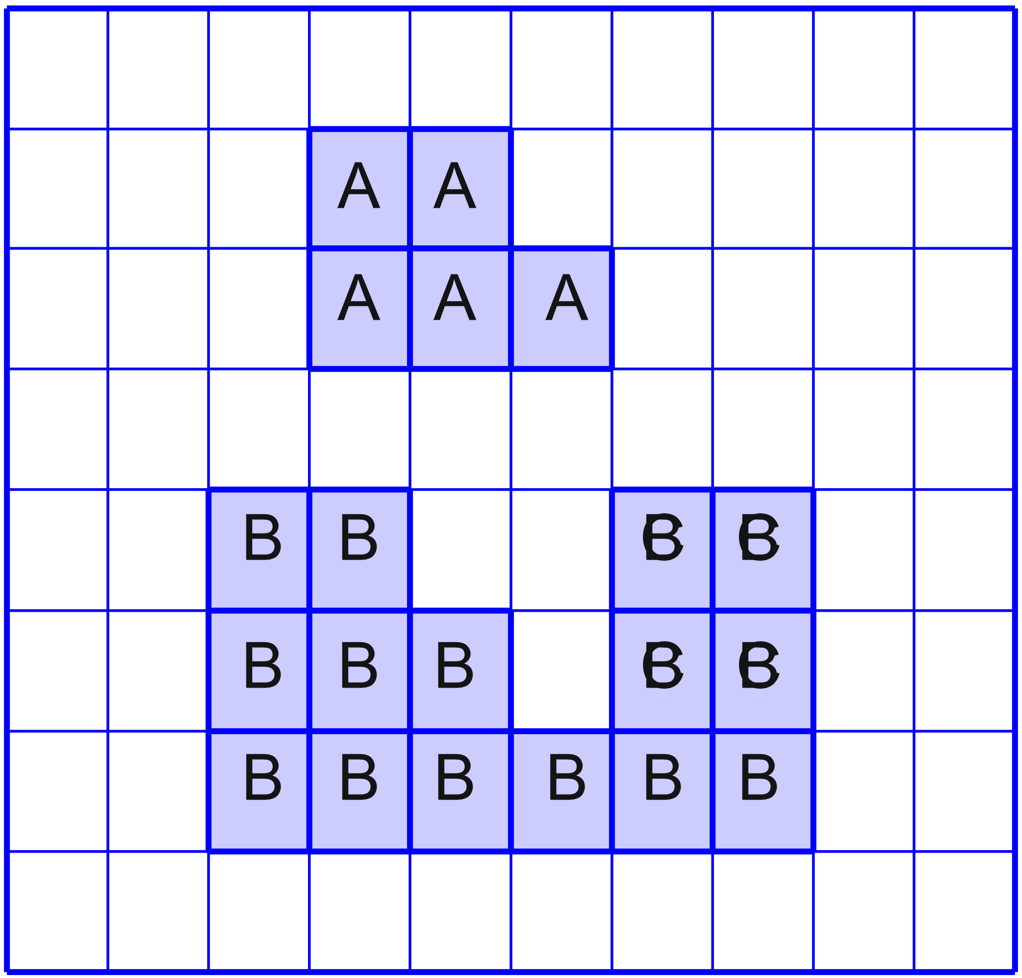
CONNECTED COMPONENT LABELING: FIRST PASS



EQUIVALENCE:

B=C

CONNECTED COMPONENT LABELING: SECOND PASS



TWO OBJECTS!

CONNECTED COMPONENT LABELING: TABLE OF EQUIVALENCES

2	=	5	16	=	27	16	=	50	50	=	81	112	=	127
5	=	9	5	=	28	5	=	39	50	=	86	112	=	134
2	=	5	27	=	34	34	=	51	50	=	86	112	=	137
5	=	10	16	=	37	5	=	39	5	=	87	112	=	138
5	=	10	5	=	39	34	=	46	111	=	112			
5	=	10	5	=	39	5	=	66	112	=	113			
5	=	12	40	=	41	34	=	72	112	=	119			
5	=	16	5	=	39	34	=	72	112	=	120			
5	=	18	34	=	46	50	=	76	112	=	120			
16	=	23	34	=	46	50	=	81	112	=	122			

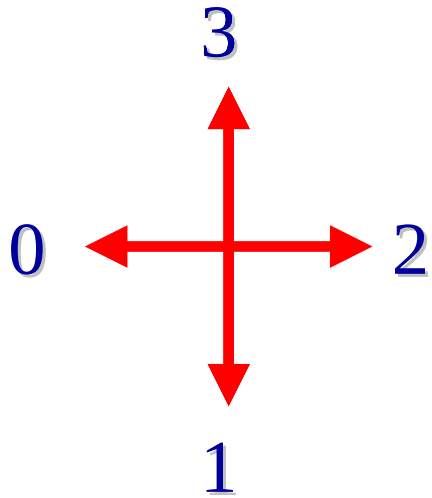
CONNECTED COMPONENT LABELING: TABLE OF EQUIVALENCES

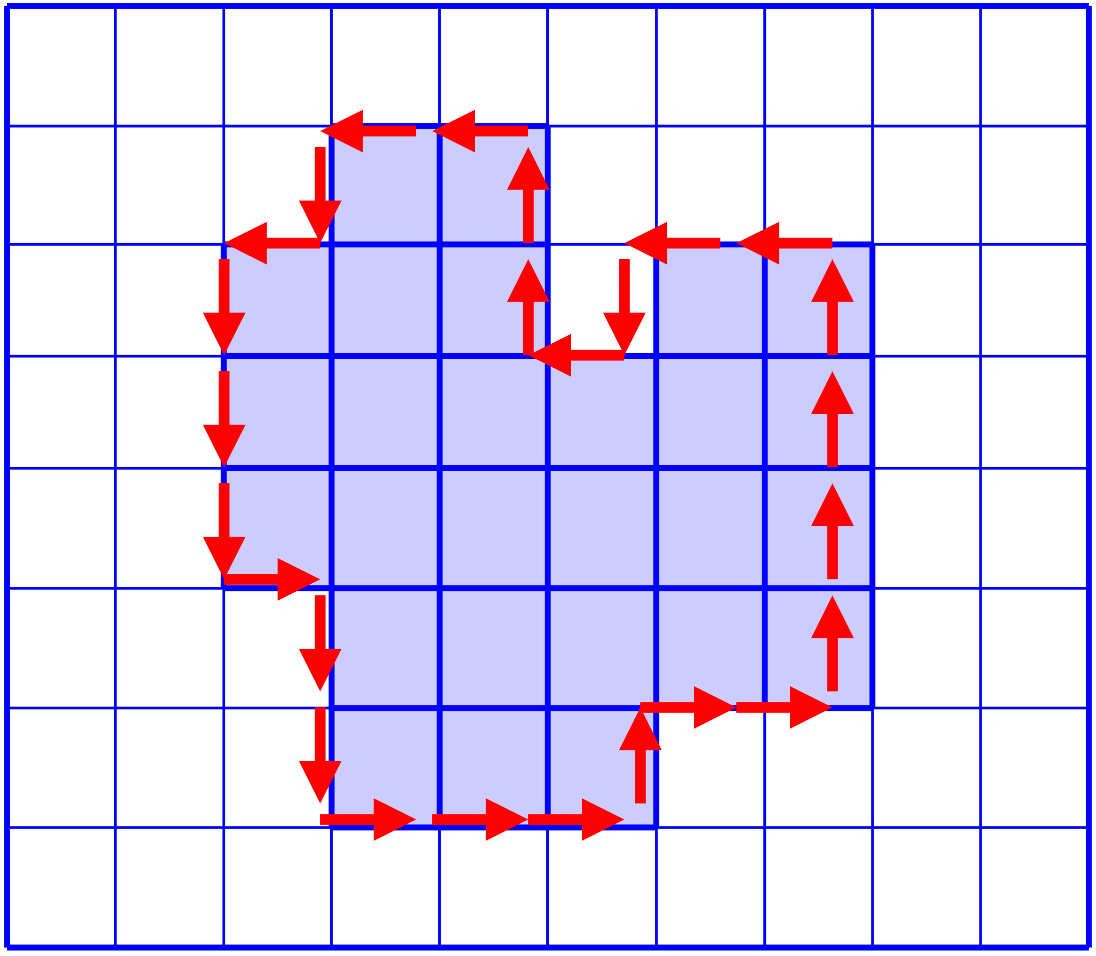
2	=	5		2	=	37		2	=	86		111	=	138
2	=	9		2	=	39		2	=	87				
2	=	10		40	=	41		111	=	112				
2	=	12		2	=	46		111	=	113				
2	=	16		2	=	50		111	=	119				
2	=	18		2	=	51		111	=	120				
2	=	23		2	=	66		111	=	122				
2	=	27		2	=	72		111	=	127				
2	=	28		2	=	76		111	=	134				
2	=	34		2	=	81		111	=	137				

IS THERE A MORE COMPUTATIONALLY EFFICIENT TECHNIQUE FOR SEGMENTING THE OBJECTS IN THE IMAGE?

- Contour tracking/border following identify the pixels that fall on the boundaries of the objects, i.e., pixels that have a neighbor that belongs to the *background class or region*.
- There are two “standard” code definitions used to represent boundaries: code definitions based on 4-connectivity (*crack* code) and code definitions based on 8-connectivity *(chain code*)*.*

BOUNDARY REPRESENTATIONS: 4-CONNECTIVITY (*CRACK CODE*)

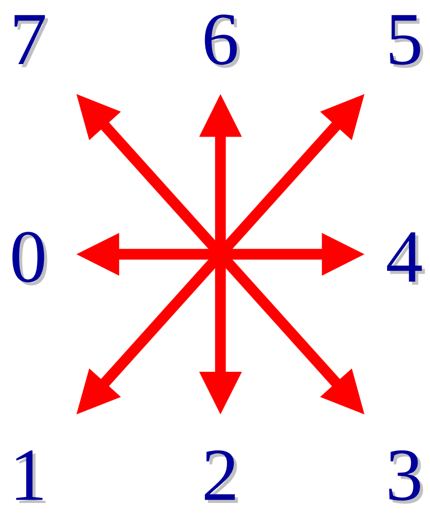


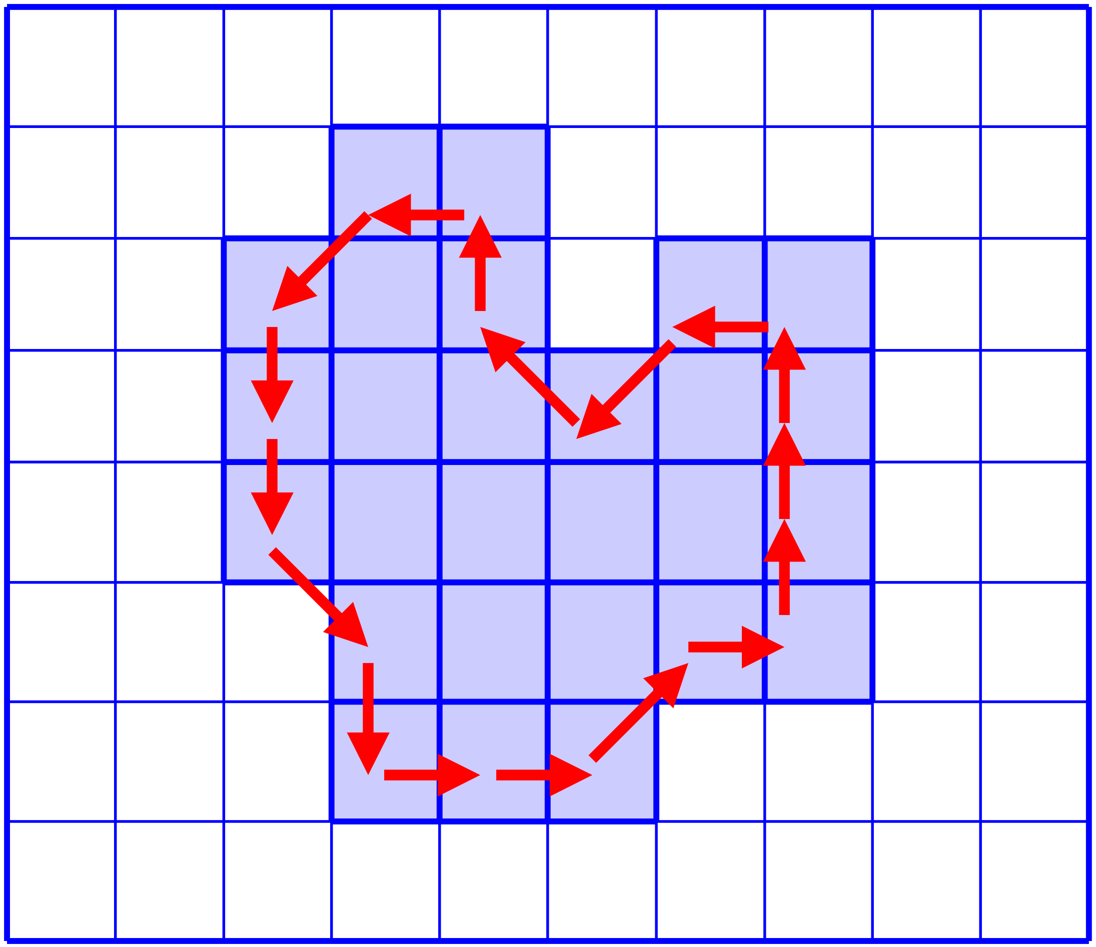


CRACK CODE:

10111211222322333300103300

BOUNDARY REPRESENTATIONS: 8-CONNECTIVITY (*CHAIN CODE*)





CHAIN CODE:

12232445466601760

CONTOUR TRACKING ALGORITHM FOR GENERATING CRACK CODE

- Identify a pixel **P** that belongs to the class “objects” and a neighboring pixel (4 neighbor connectivity) **Q** that belongs to the class “background”.
- Depending on the relative position of **Q** relative to **P**, identify pixels **U** and **V** as follows:

CODE 0

V	Q
U	P

CODE 1

Q	P
V	U

CODE 2

P	U
Q	V

CODE 3

U	V
P	Q

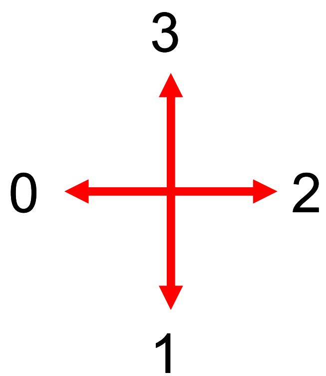
CONTOUR TRACKING ALGORITHM

- Assume that a pixel has a value of "1" if it belongs to the class "object" and "0" if it belongs to the class "background".
- Pixels **U** and **V** are used to determine the next "move" (i.e., the next element of crack code) as summarized in the following truth table:

U	V	P'	Q'	TURN	CODE*
X	1	V	Q	RIGHT	CODE-1
1	0	U	V	NONE	CODE
0	0	P	U	LEFT	CODE+1

*Implement as a modulo 4 counter

CONTOUR TRACKING ALGORITHM



CODE 0

V	Q
U	P

CODE 1

Q	P
V	U

CODE 2

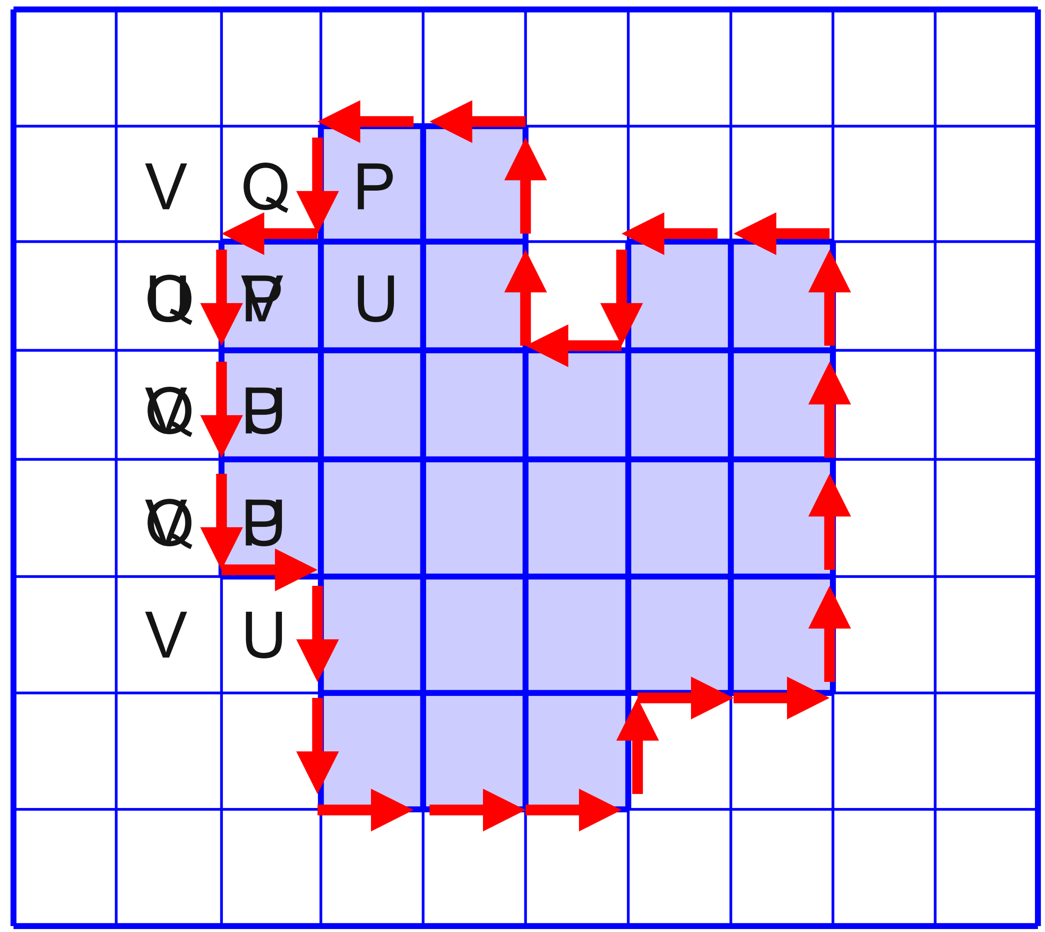
P	U
Q	V

CODE 3

U	V
P	Q

U	V	P’	Q’	TURN	CODE*
X	1	V	Q	RIGHT	CODE-1
1	0	U	V	NONE	CODE
0	0	P	U	LEFT	CODE+1

*Implement as a modulo 4 counter



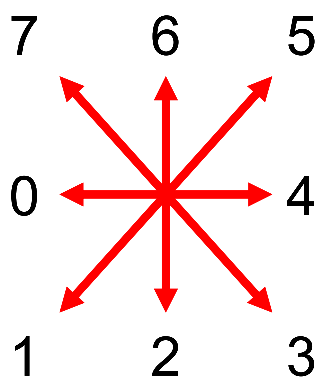
CONTOUR TRACKING ALGORITHM FOR GENERATING CHAIN CODE

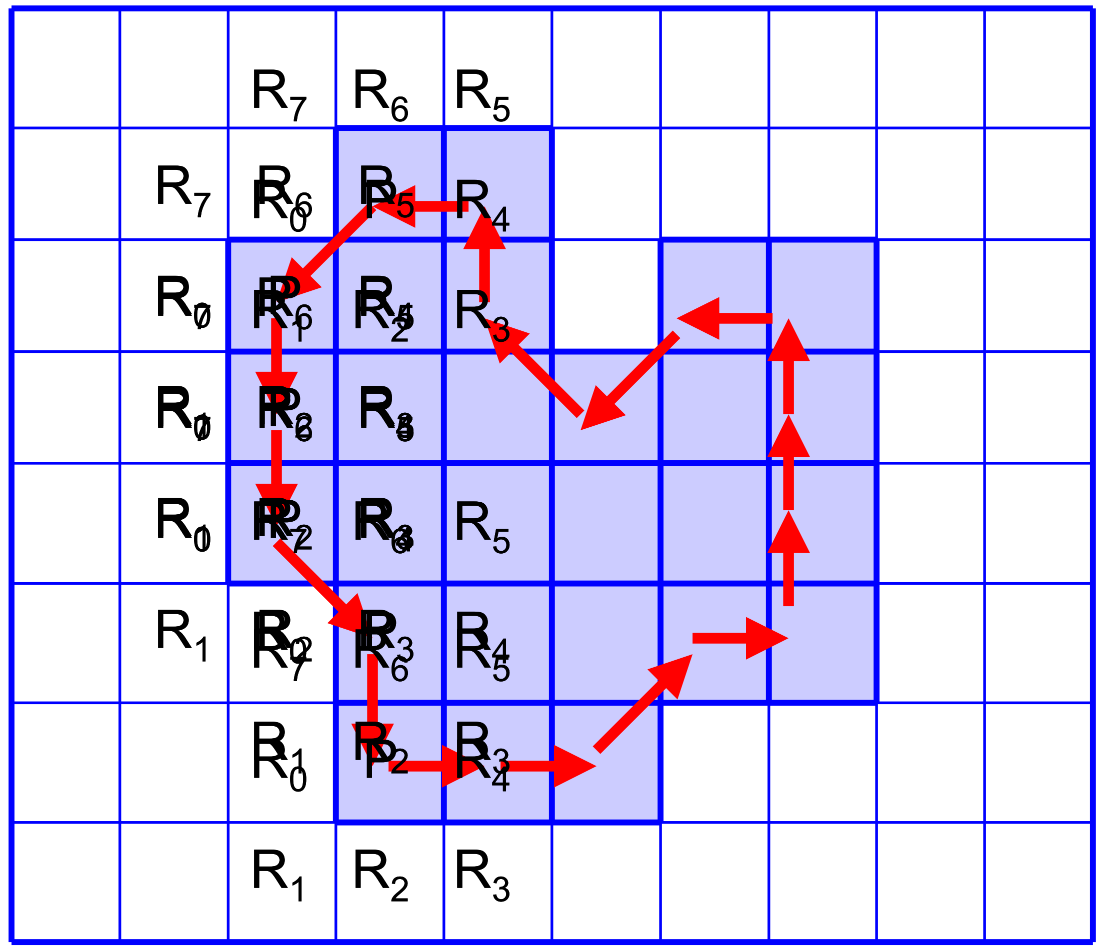
- Identify a pixel **P** that belongs to the class "objects" and a neighboring pixel (4 neighbor connectivity) $\mathbf{R_0}$ that belongs to the class "background". Assume that a pixel has a value of "1" if it belongs to the class "object" and "0" if it belongs to the class "background".

- Assign the 8-connectivity neighbors of **P** to $\mathbf{R_0}$, $\mathbf{R_1}$, …, **R7** as follows:

R_7	R_6	R_5
R_0	P	R_4
R_1	R_2	R_3

CONTOUR TRACKING ALGORITHM FOR GENERATING CHAIN CODE





ALGORITHM:

i=0

WHILE (R_i==0) { i++ }

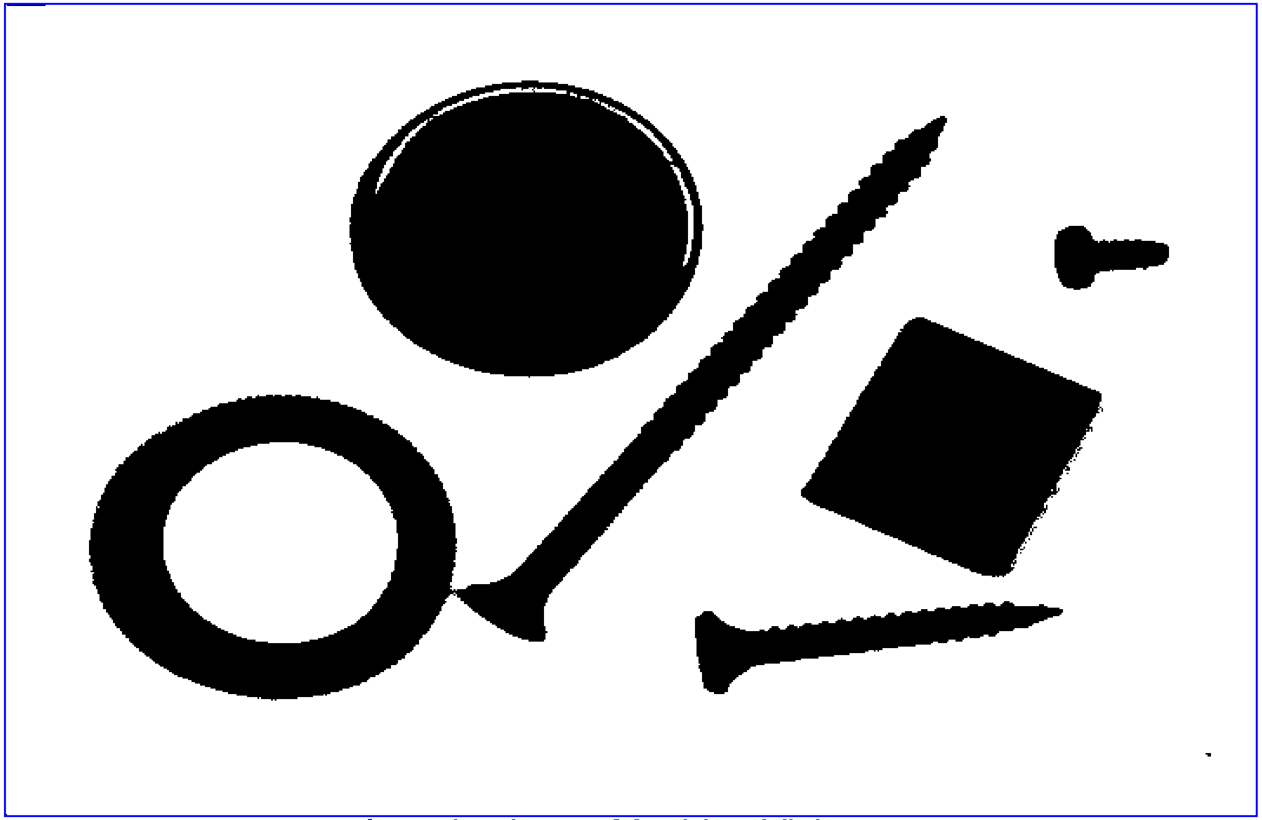
•Move P to R_i

•Set i=6 for next search

OBJECT RECOGNITION – BLOB ANALYSIS

- Once the image has been segmented into classes representing the objects in the image, the next step is to generate a high level *description* of the various objects.
- A comprehensive set of form parameters describing each object or region in an image is useful for object recognition.
- Ideally the form parameters should be independent of the object's position and orientation as well as the distance between the camera and the object (i.e., scale factor).

What are some examples of form parameters that would be useful in identifying the objects in the image below?



OBJECT RECOGNITION – BLOB ANALYSIS

- Examples of form parameters that are invariant with respect to position, orientation, and scale:
  - Number of holes in the object
  - Compactness or Complexity: $(\text{Perimeter})^2/\text{Area}$
  - Moment invariants
- All of these parameters can be evaluated during contour following.

GENERALIZED MOMENTS

•Shape features or form parameters provide a high level description of objects or regions in an image

•Many shape features can be conveniently represented in terms of moments. The **(p,q)th** moment of a region **R** defined by the function **f(x,y)** is given by:

$$m_{pq} = \iint_R x^p y^q f(x,y)\,dx\,dy$$

GENERALIZED MOMENTS

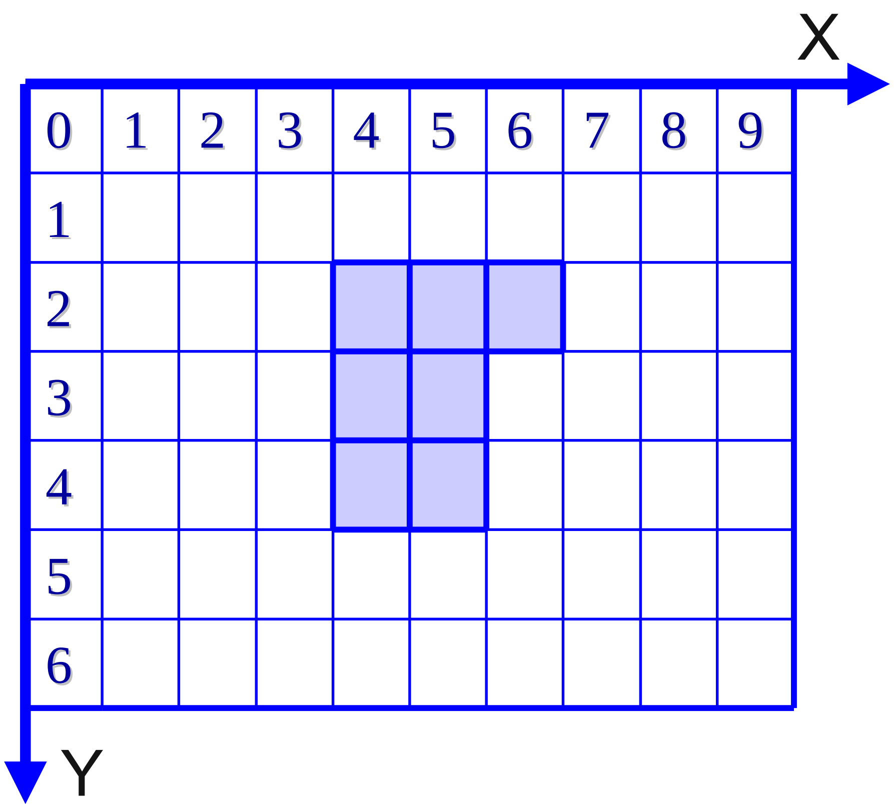
•In the case of a digital image of size **n** by **m** pixels, this equation simplifies to:

$$M_{ij} = \sum_{x=1}^{n} \sum_{y=1}^{m} x^i y^j f(x, y)$$

•For binary images the function f(x,y) takes a value of 1 for pixels belonging to class “object” and “0” for class “background”.

GENERALIZED MOMENTS

$$M_{ij} = \sum_{x=1}^{n} \sum_{y=1}^{m} x^i y^j f(x,y)$$



i	j	M_{ij}
0	0	7
1	0	33
0	1	20
2	0	159
0	2	64
1	1	93

Area

Moment of Inertia

SOME USEFUL MOMENTS

- The center of mass of a region can be defined in terms of generalized moments as follows:

$$\overline{X} = \frac{M_{10}}{M_{00}} \qquad \overline{Y} = \frac{M_{01}}{M_{00}}$$

SOME USEFUL MOMENTS

- The moments of inertia relative to the center of mass can be determined by applying the general form of the parallel axis theorem:

$$\overline{M}_{02} = M_{02} - \frac{M_{01}^2}{M_{00}}$$

$$\overline{M}_{20} = M_{20} - \frac{M_{10}^2}{M_{00}}$$

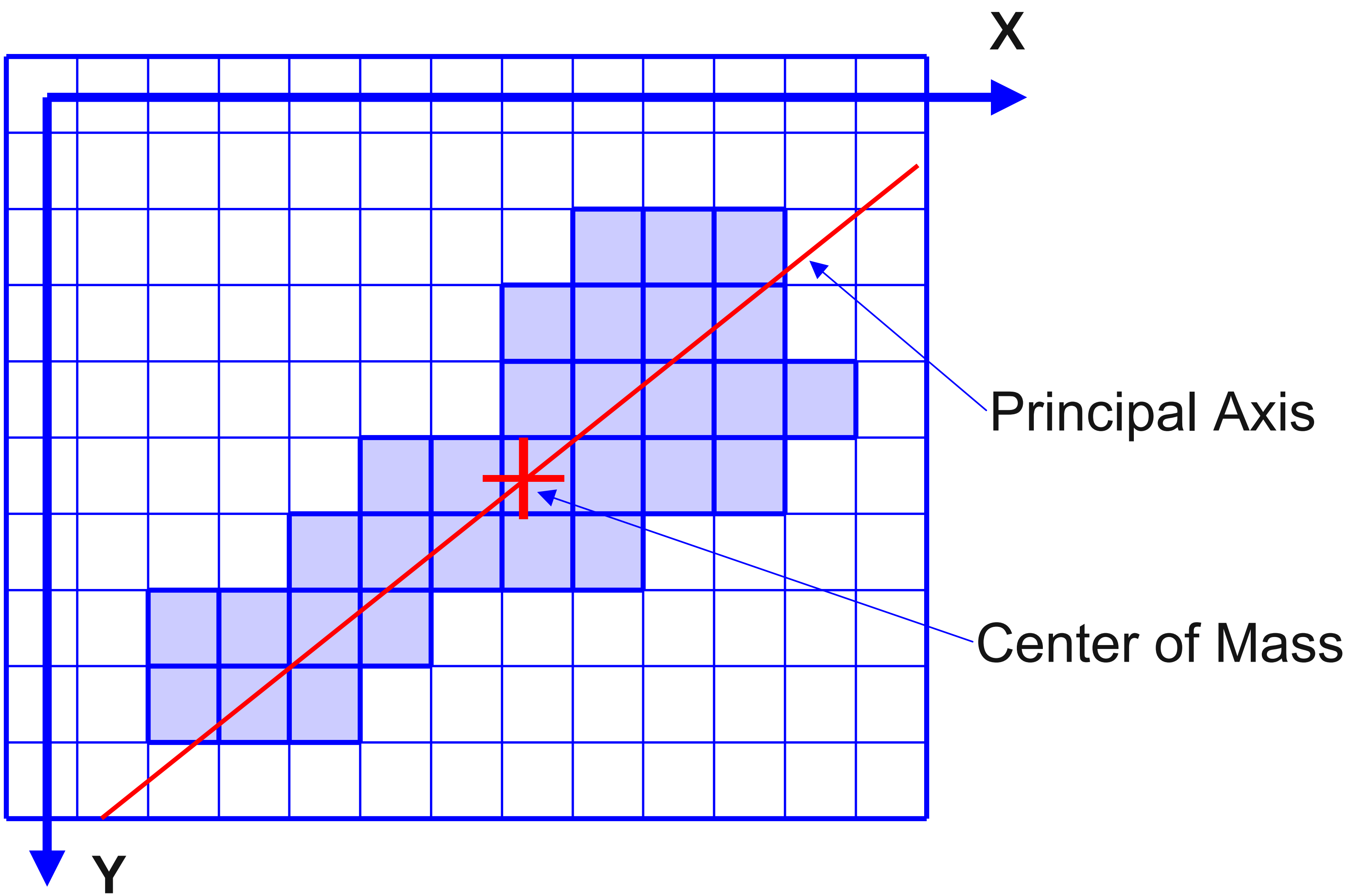
$$\overline{M}_{11} = M_{11} - \frac{M_{10} M_{01}}{M_{00}}$$

SOME USEFUL MOMENTS

- The principal axis of an object is the axis passing through the center of mass which yields the minimum moment of inertia.
- This axis forms an angle θ with respect to the X axis.
- The principal axis is useful in robotics for determining the orientation of randomly placed objects.

$$TAN\, 2\theta = \frac{2\overline{M}_{11}}{\overline{M}_{20} - \overline{M}_{02}}$$

Example



SOME (MORE) USEFUL MOMENTS

- The minimum/maximum moment of inertia about an axis passing through the center of mass are given by:

$$\overline{I}_{MIN} = \frac{\overline{M}_{02} + \overline{M}_{20}}{2} - \frac{\sqrt{(\overline{M}_{02} - \overline{M}_{20})^2 + 4\overline{M}_{11}^{\,2}}}{2}$$

$$\overline{I}_{MAX} = \frac{\overline{M}_{02} + \overline{M}_{20}}{2} + \frac{\sqrt{(\overline{M}_{02} - \overline{M}_{20})^2 + 4\overline{M}_{11}^{\,2}}}{2}$$

SOME (MORE) USEFUL MOMENTS

- The following moments are independent of position, orientation, and reflection. They can be used to identify the object in the image.

$$\phi_1 = \overline{M}_{20} + \overline{M}_{02}$$

$$\phi_2 = (\overline{M}_{20} + \overline{M}_{02})^2 + 4\overline{M}_{11}^2$$

SOME (MORE) USEFUL MOMENTS

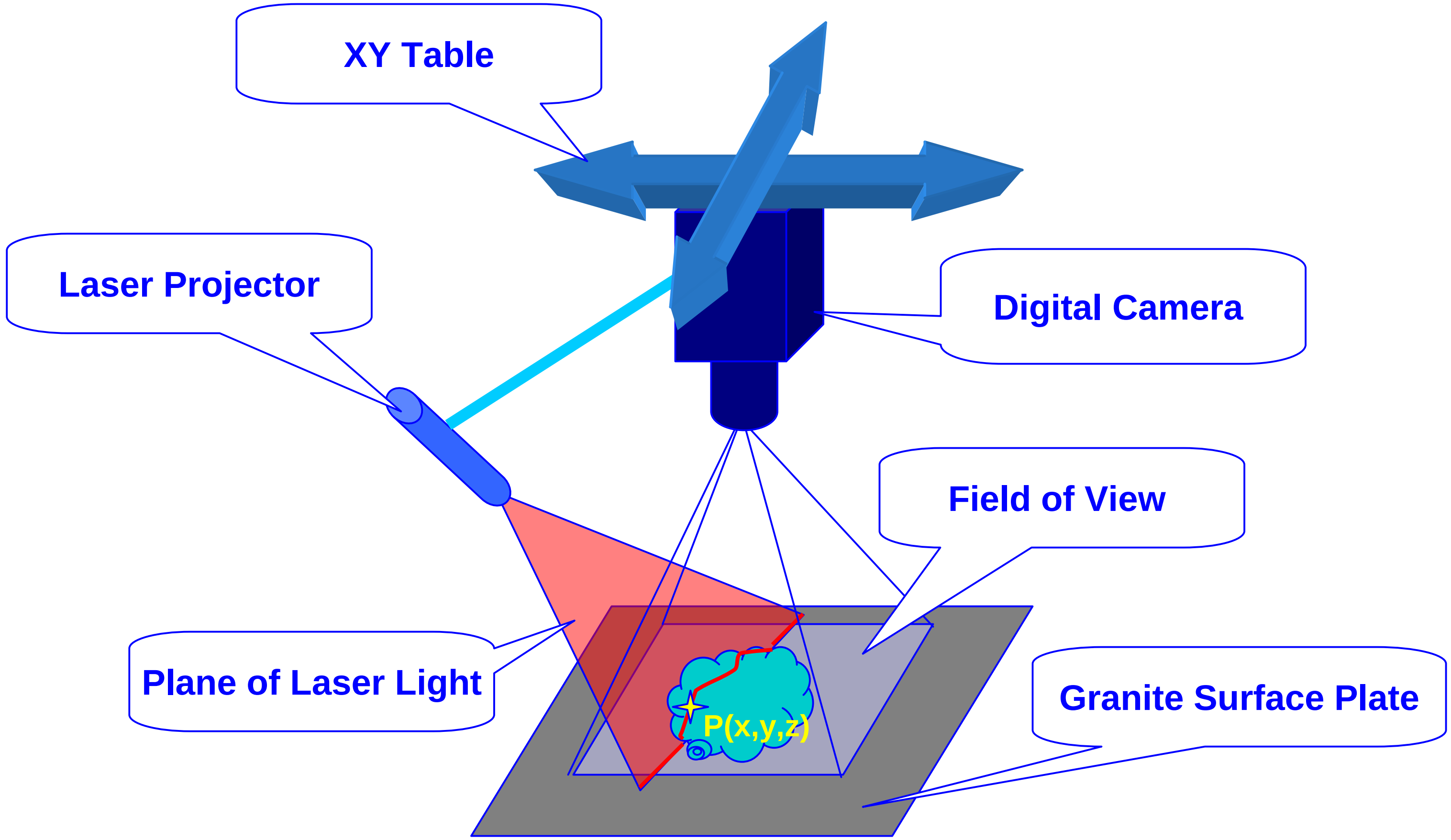
- The following moments are normalized with respect to area. They are independent of position, orientation, reflection, and scale.

$$\psi_1 = \frac{\phi_1}{M_{00}^2} \qquad \psi_2 = \frac{\phi_2}{M_{00}^4}$$

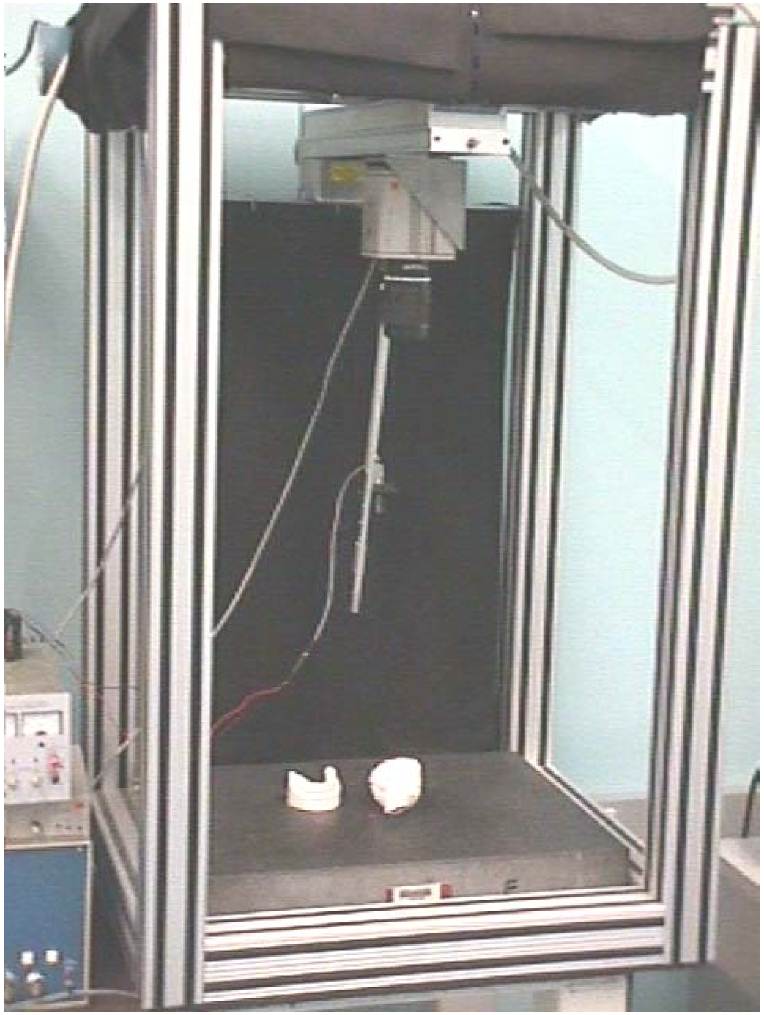
EVALUATING MOMENTS DURING CONTOUR TRACKING

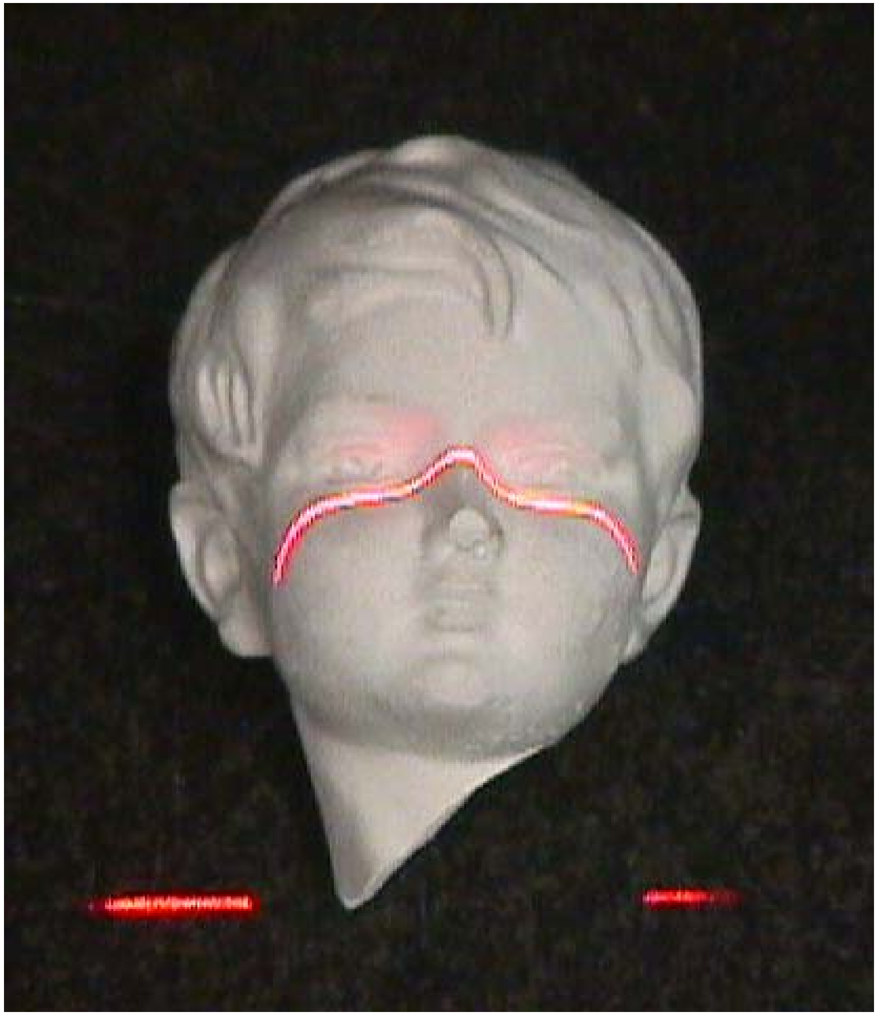
- Generalized moments are computed by evaluating a double (i.e., surface) integral over a region of the image.
- The surface integral can be transformed into a line integral around the boundary of the region by applying Green's Theorem.
- The line integral can be easily evaluated during contour tracking.
- The process is analogous to using a planimeter to graphically evaluate the area of a geometric figure.

3D MACHINE VISION SYSTEM

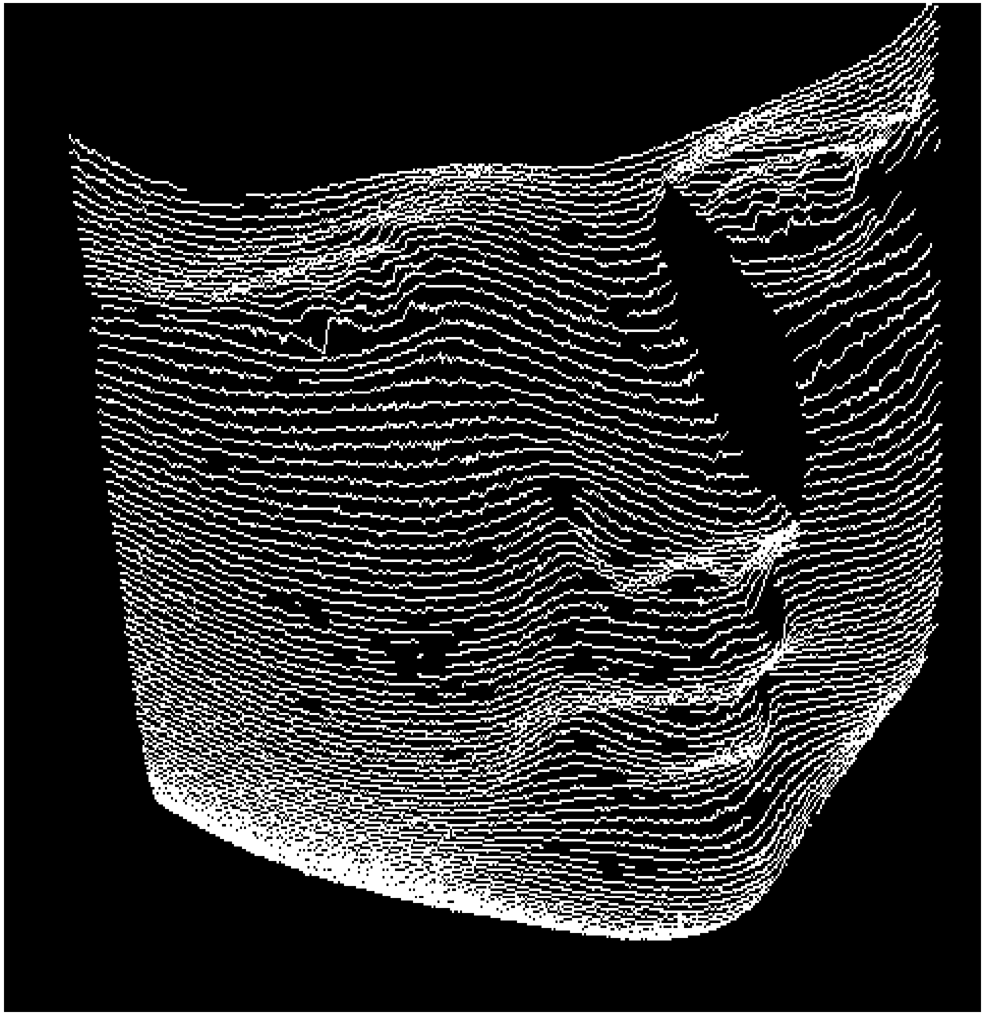


3D MACHINE VISION SYSTEM

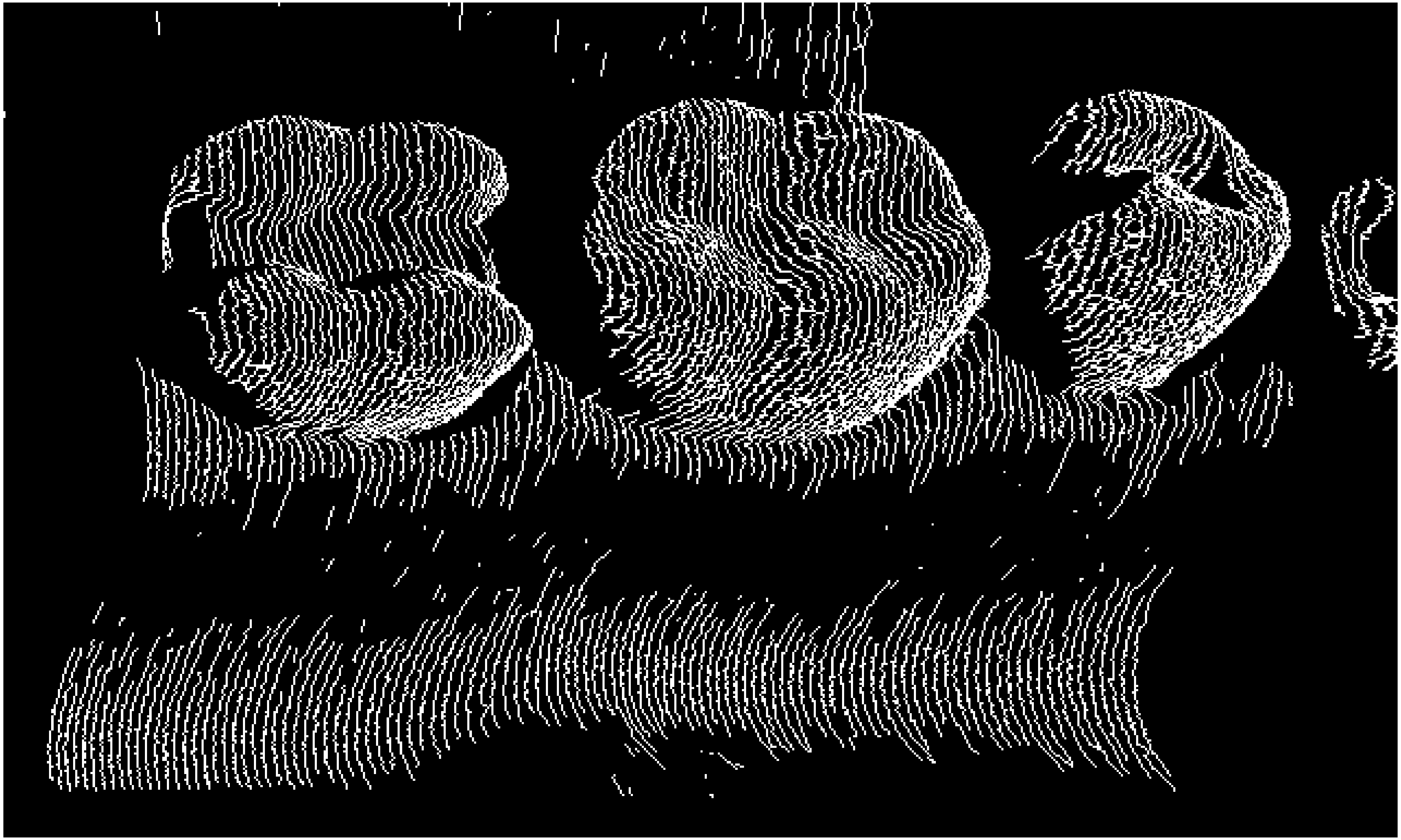




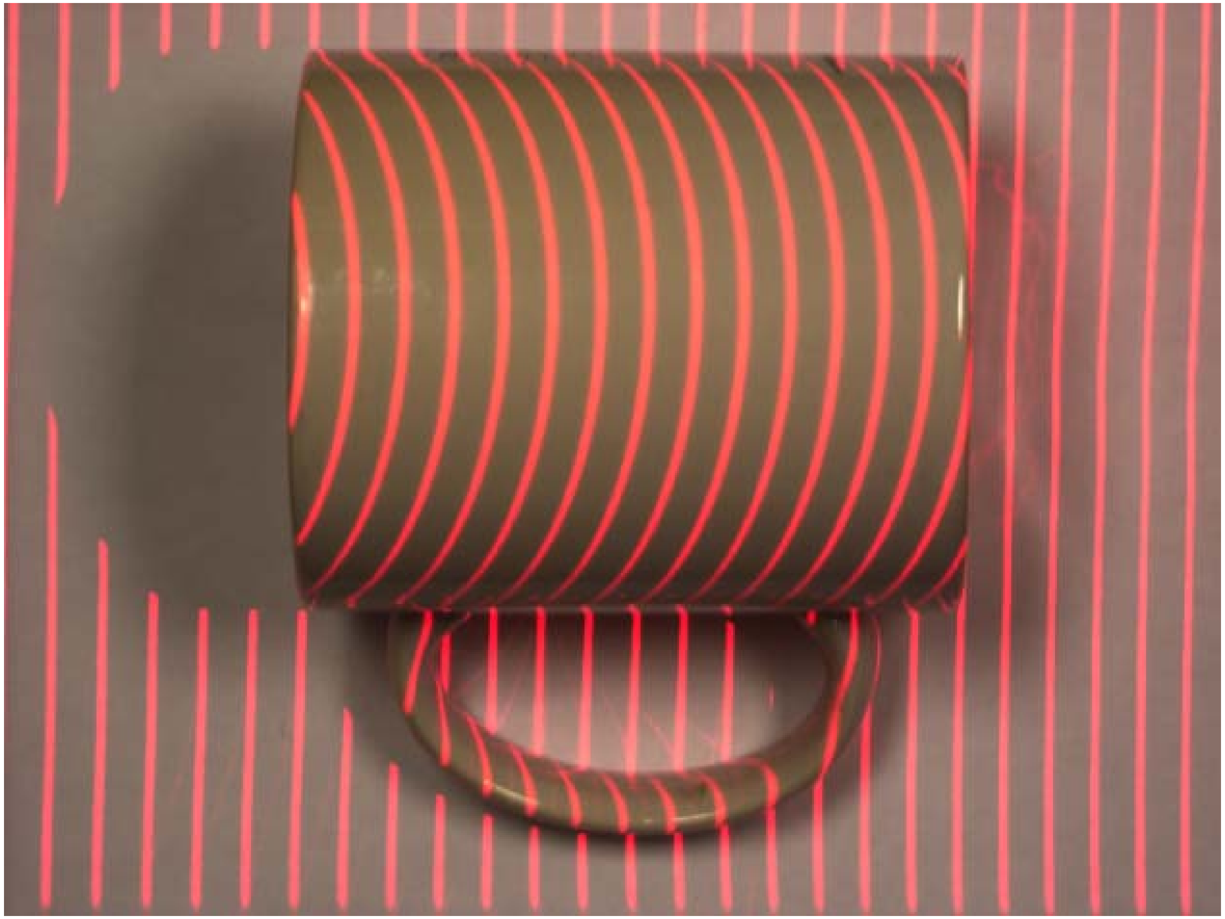
3D MACHINE VISION SYSTEM



3D MACHINE VISION SYSTEM



3D MACHINE VISION SYSTEM



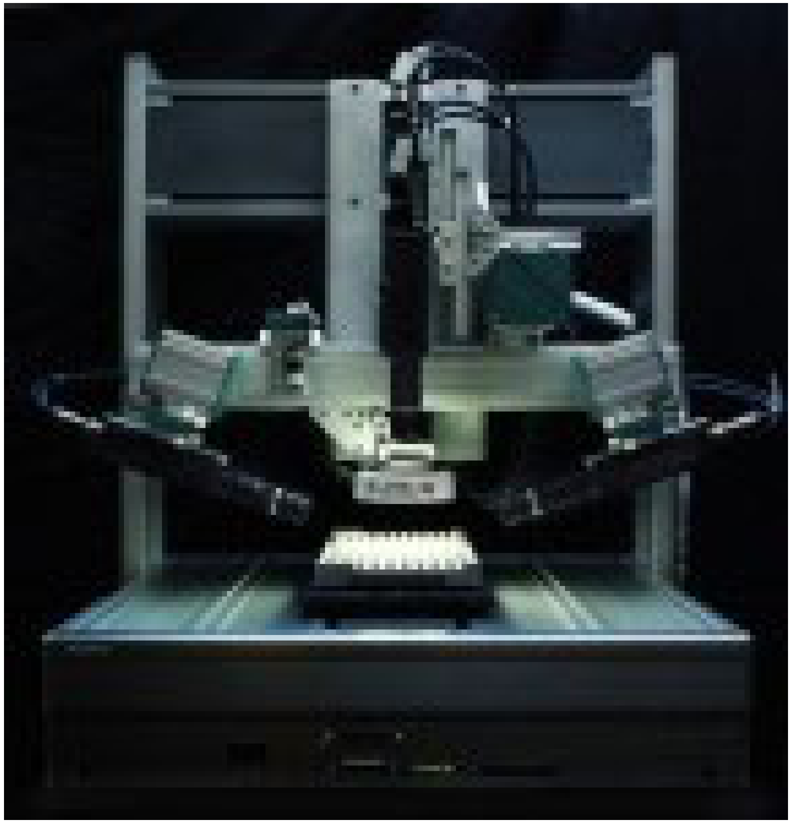
Commercial Machine Vision Definition

"Machine vision is the capturing of an image (a snapshot in time), the conversion of the image to digital information, and the application of processing algorithms to extract useful information about the image for the purposes of pattern recognition, part inspection, or part positioning and orientation"….Ed Red

Imaging System Components | Image Labs Key Components | Machine Vision Engineering Solutions | CatPro and Catalytic Inspection

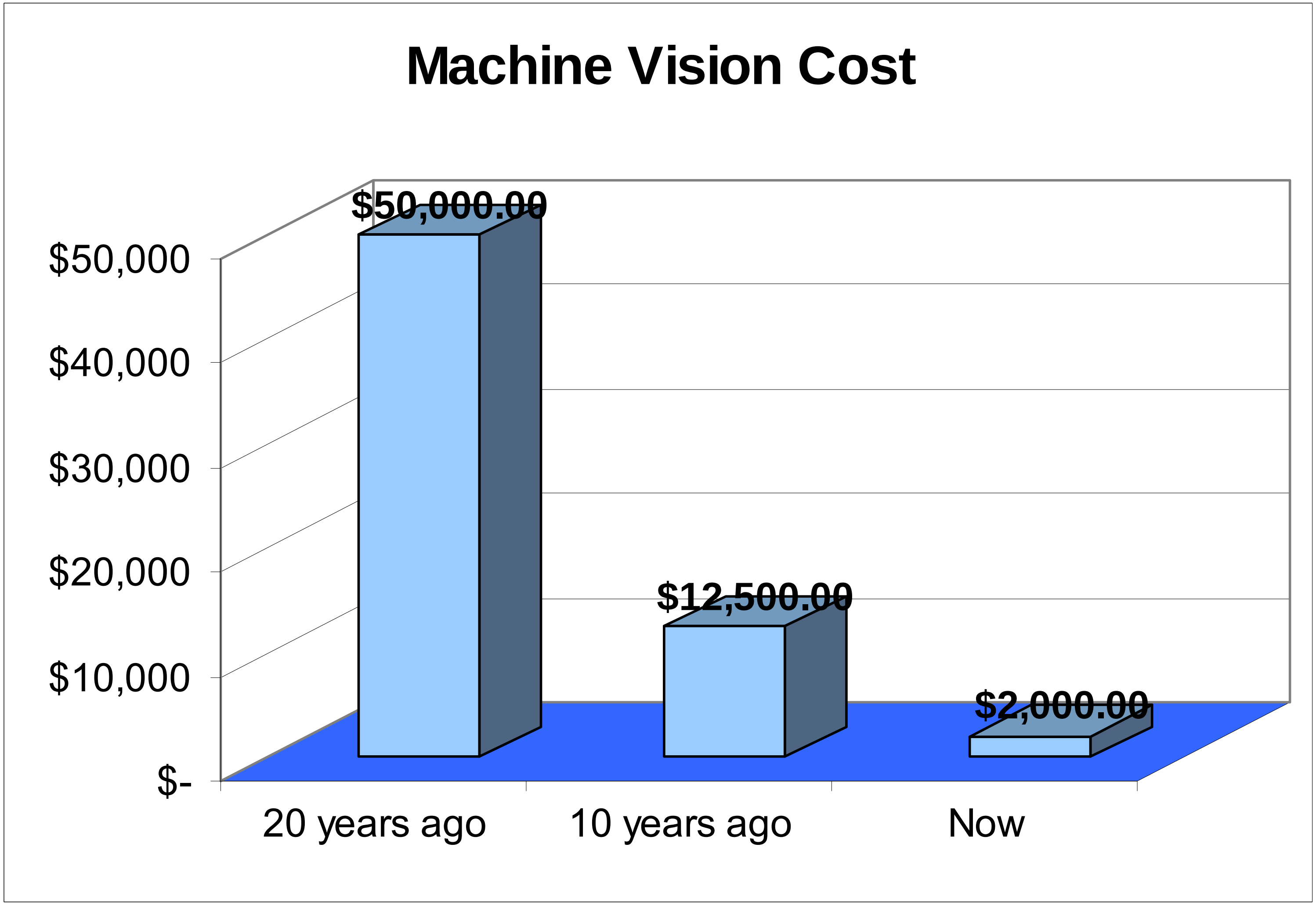
Current State

Cheap and **Easy** to Use



- The ***Sony approved Scorpion Robot Inspection Starter Kit*** contains everything you need for bringing your Scorpion Robot Inspection project to life.
- The kit includes a Scorpion Enterprise software license
- new high quality Sony XCD-710 (CR) camera (XGA resolution)
- Sony Desktop Robot
- 2 days training course
- A standard and configurable user interface paired with innovative, easy-to-use and robust imaging tools
- **$1995.00**

Costs



Data Source: http://www.qualitydigest.com/oct97/html/machvis.html

Costs

Savings from using machine vision

- Cost of recruiting and training
- Scrap/rework created while learning a new job
- Average workers' compensation paid for injuries
- Average educational grant per employee
- Personnel/payroll department costs per employee

Where, What, Whom

Machine vision now has a wide range of installations in high-production industries including:

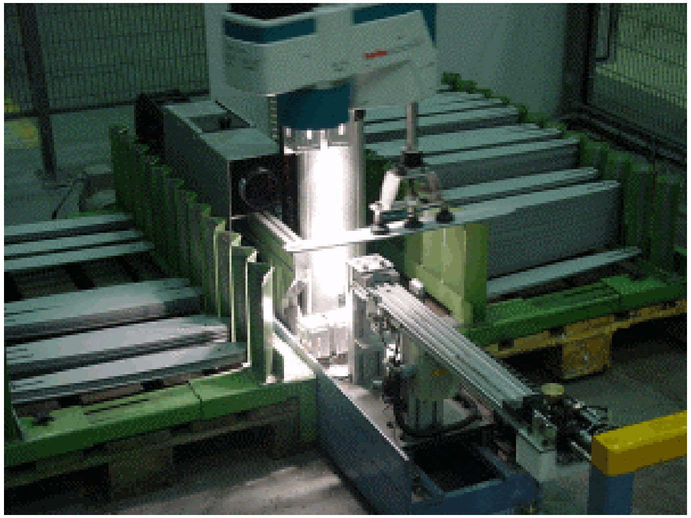
- Semiconductor
- Electronic
- Automotive
- Container
- Pharmaceutical
- medical device
- Plastic

- Chemicals
- Food
- Footwear
- Textiles
- Printing
- Wood/forest products
- Fabricated metal

Machine vision can be found wherever parts are formed and packaged.

Where, What, Whom

- Automotive
  - fuse box inspection,
  - tire tread recognition,
  - power train inspection and
  - sheet metal inspection.
- Electronics
  - bare-board manufacturer
    - (inspect artwork, inner/outer layer circuit patterns, drill-hole patterns),
  - board assembler
    - (inspect solder paste/epoxy for presence and volume, check co-planarity of component leads, verify presence and position of components pre-solder, verify presence and position of components post-solder, and solder presence/absence and properties),
  - assembly
    - (alignment to assure position of screen-printed patterns, epoxy, component placement, and board pattern position.)



Where, What, Whom

- Food
  - fruit and vegetable sorting and grading,
  - automatic portioning,
  - inspection for foreign objects, and
  - general package-line applications
- Beverage
  - quality inspection of containers,
  - fill level inspection, and
  - closure inspection are among the leading applications

Where, What, Whom

- Aerospace
  - Design of a new sensor system with improved performance for accurately locating and measuring the parameters of holes in aerospace components
  - The specification for the sensor system included the ability to locate and measure both conventional and countersunk holes, in a range of surfaces including aluminum and the latest graphite-based materials
- Work Zone Monitoring uses:
  - 1300 x 1030 All Digital Camera
  - Image Capture and License Plate Reader
  - Fiber Optic Transmission
  - Software Plate Reader
  - PCIbus Wintel Architecture

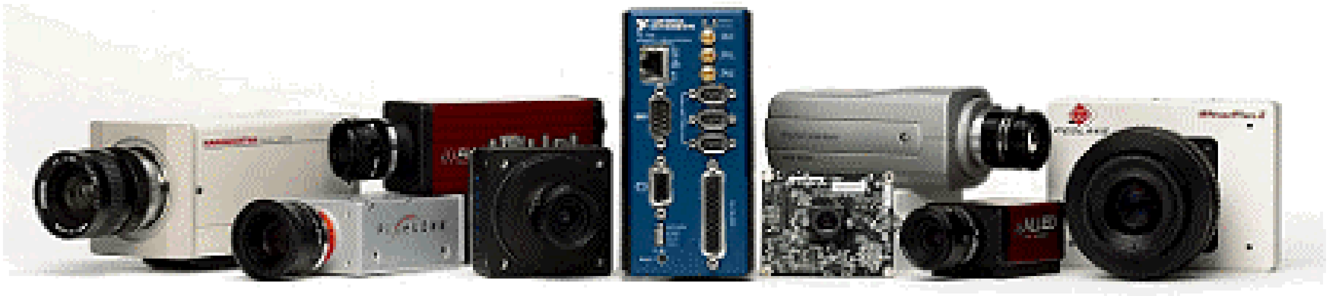
Industry Example

Supporting Technology

SOFTWARE: 7 Things to Consider When Choosing Vision Software

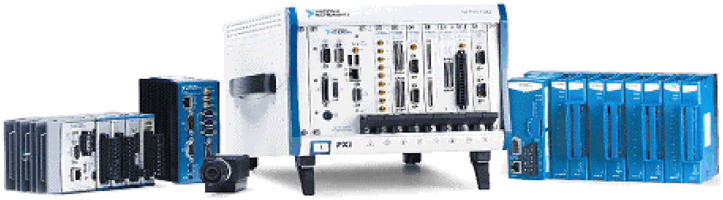
Camera Choice

- The first consideration when picking vision software is to determine if it works with the camera that is best suited for your application.



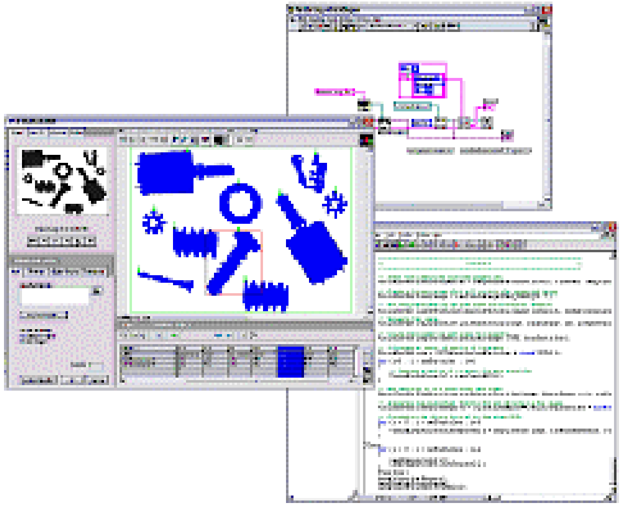
Hardware Scalability

- Because camera technologies are advancing rapidly, someday you may want to upgrade your cameras to improve image quality or measure additional features.



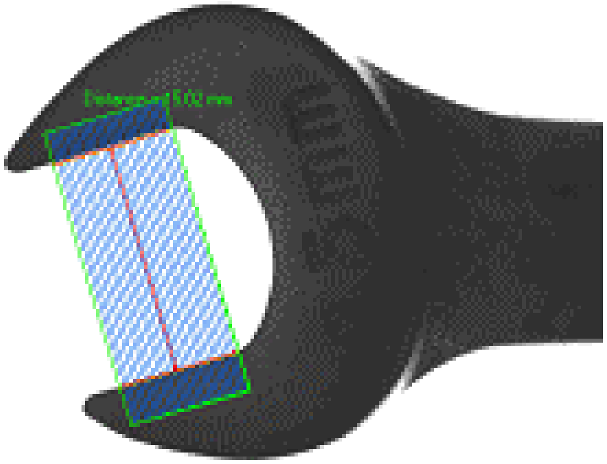
Supporting Technology

SOFTWARE: 7 Things to Consider When Choosing Vision Software



Software Ease of Use

- Once you acquire an image, the next step is to process it.



Algorithm Breadth and Accuracy

- whether the software tools can correctly and accurately measure important part or object features down to the subpixel. If the software is not accurate and reliable, then it does not matter how fast your computer is or how many pixels your camera has.

Supporting Technology

SOFTWARE: 7 Things to Consider When Choosing Vision Software

Algorithm Performance

- No matter how many hundreds of algorithms you have to choose from or how quickly you can build an application with them, if the inspection tools are inefficient and take too long to run, then much of your work goes to waste.

Integration with Other Devices

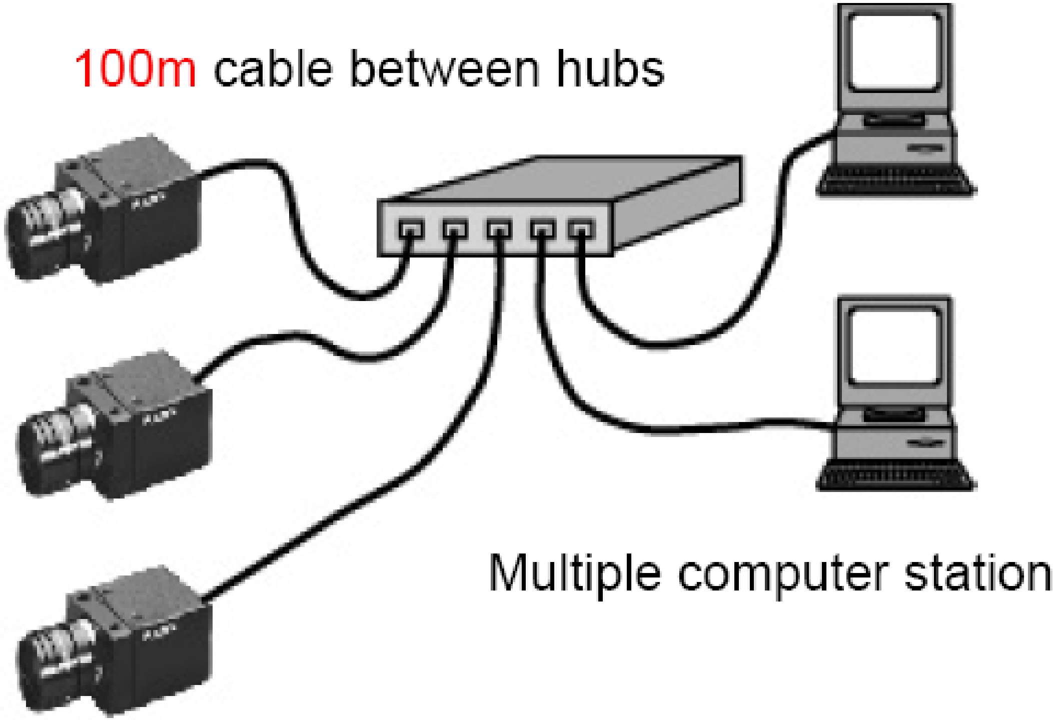
- In industrial automation, your vision application may need to control actuators to sort products; communicate inspection results to a robot controller, PLC, or programmable automation controller; save images and data to network servers; or communicate inspection parameters and results to a local or remote user interface.

Price

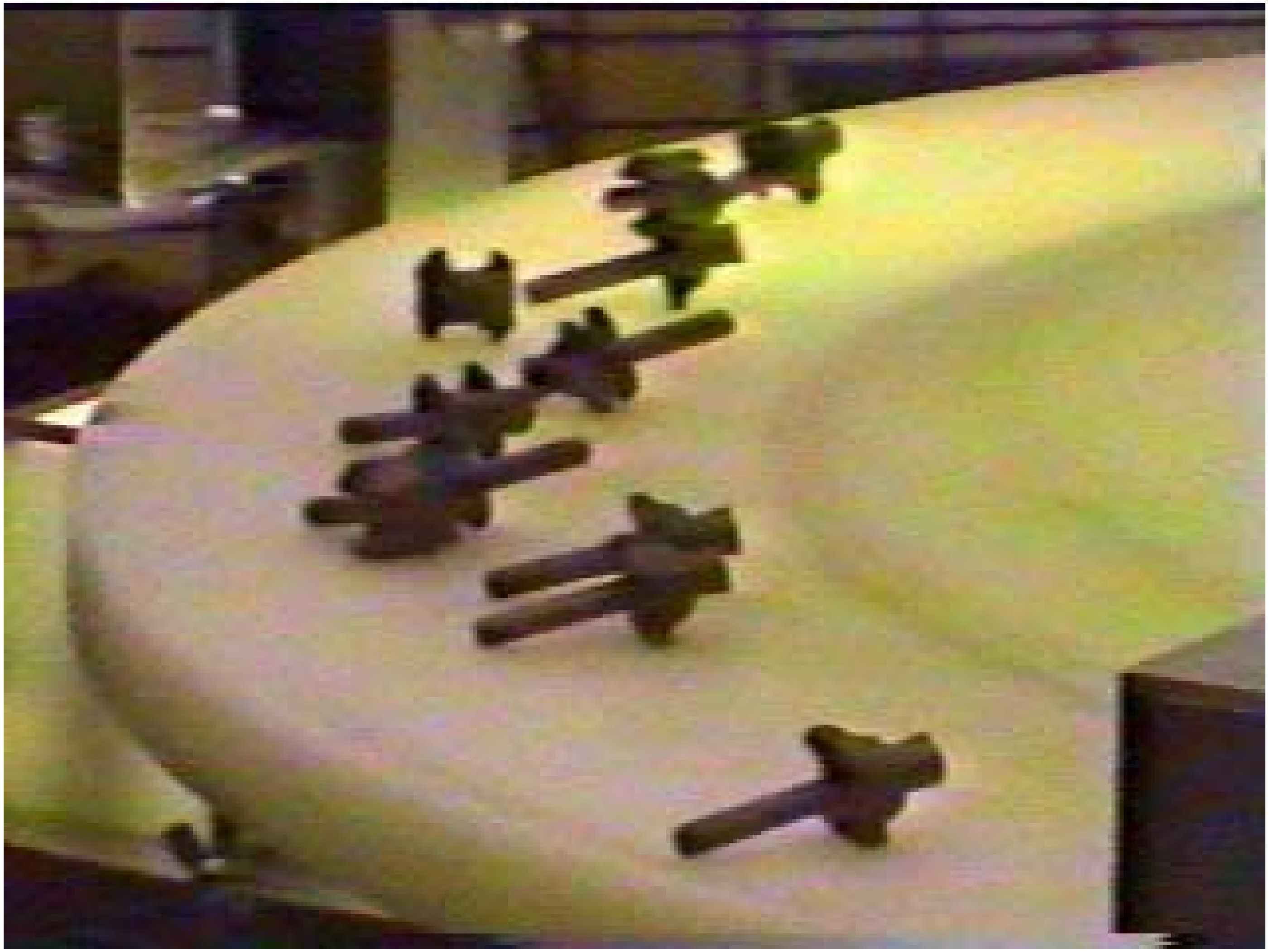
- Vision software packages come in many variations. Many cater to OEM customers by splitting up their development libraries and selling algorithms a la carte. While each individual algorithm bundle seems lower in cost, the total vision development package cost is often quite high. Add to that the cost of a license for each component, and application deployment becomes complicated as well as costly.

Standardization

- GigE Vision is the newest effort at communications interoperability. Work is on-going to develop and release a standard for the connection of vision components using a standard Gigabit **Ethernet cable and connector**.



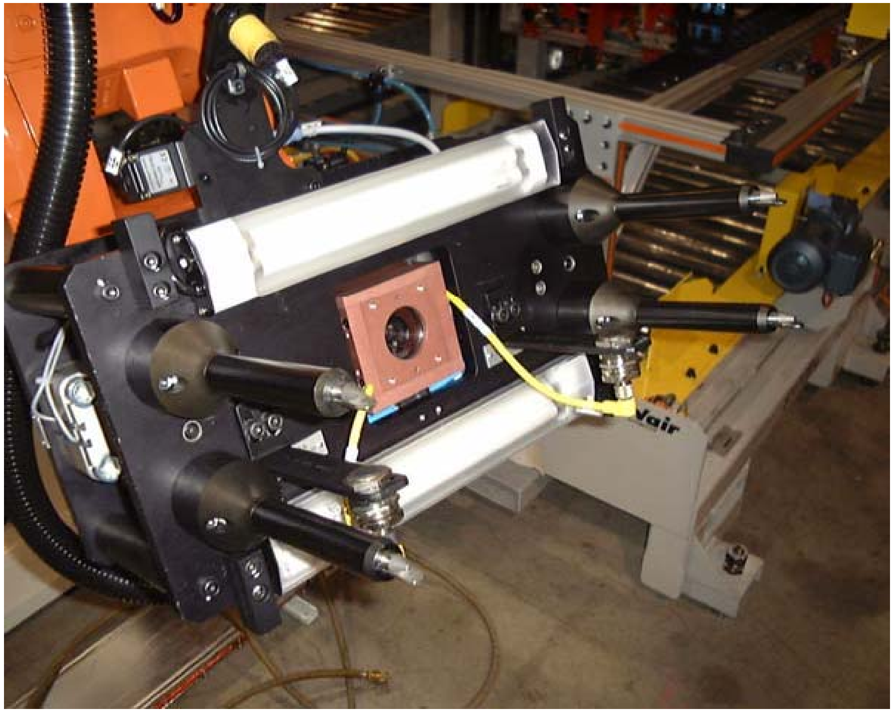
Industry Example



Single Camera 3DTM (SC3DTM)

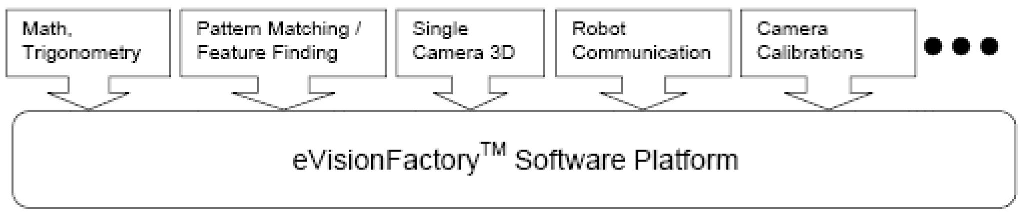
A novel technology for guidance of industrial robots in three-dimensional space

- Provides accurate 3D pose (6 d.o.f) information to industrial robots
- Machines able to ‘see’ the part while at the same time addressing the issues of reliability, usability and global supply.

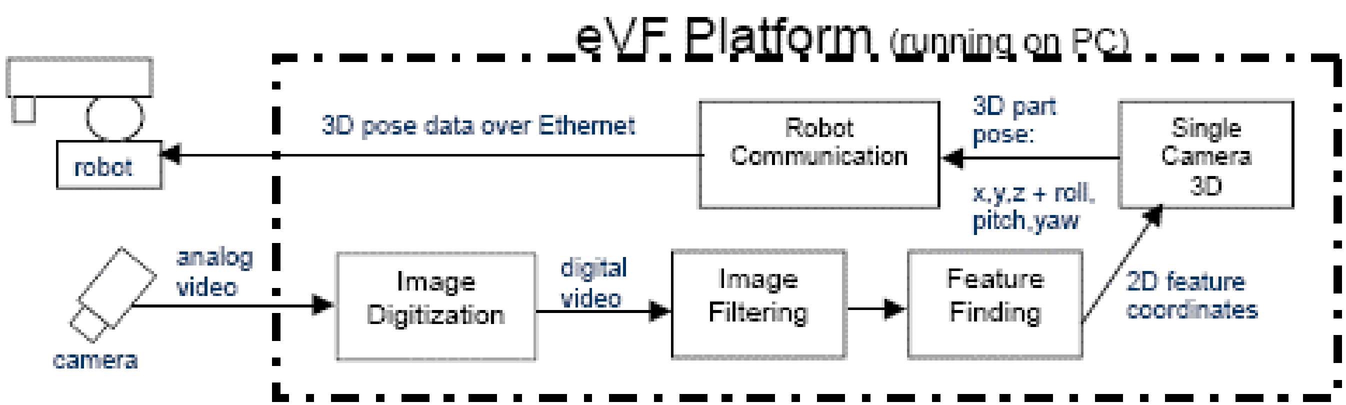


Single Camera 3DTM (SC3DTM)
A novel technology for guidance of industrial robots in three-dimensional space

- Software



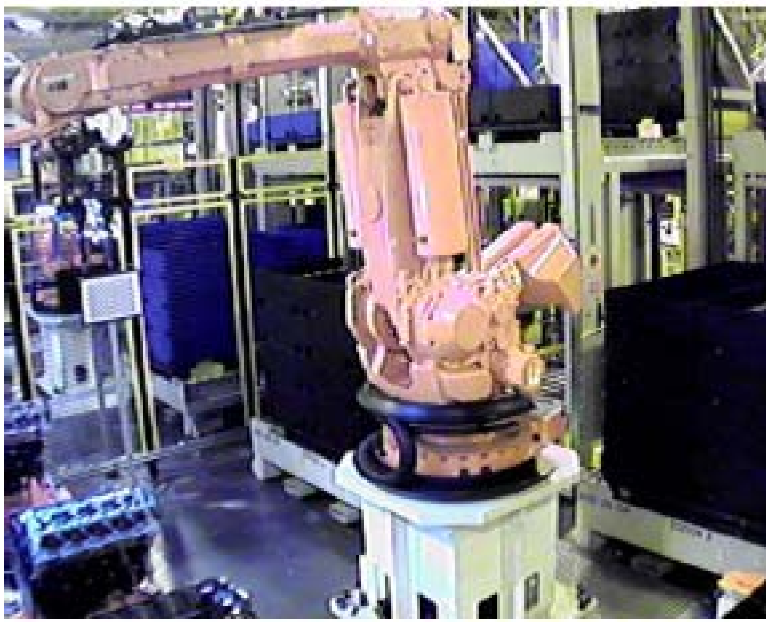
- Data Flow



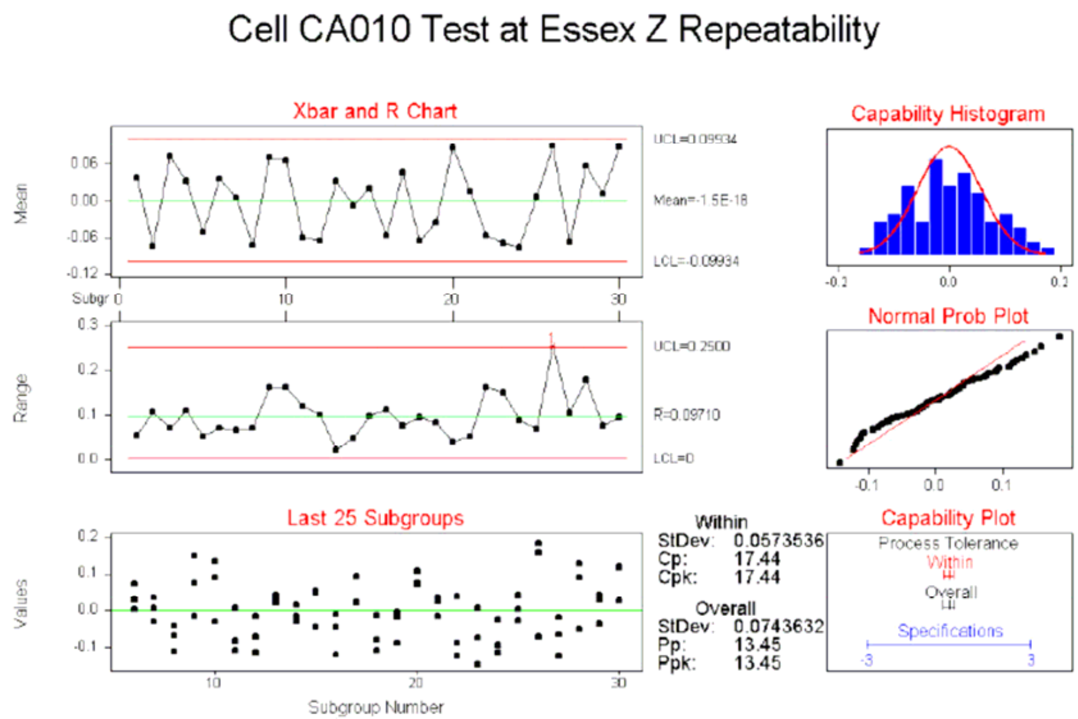
Single Camera 3DTM (SC3DTM)

A novel technology for guidance of industrial robots in three-dimensional space

Machine



Repeatability

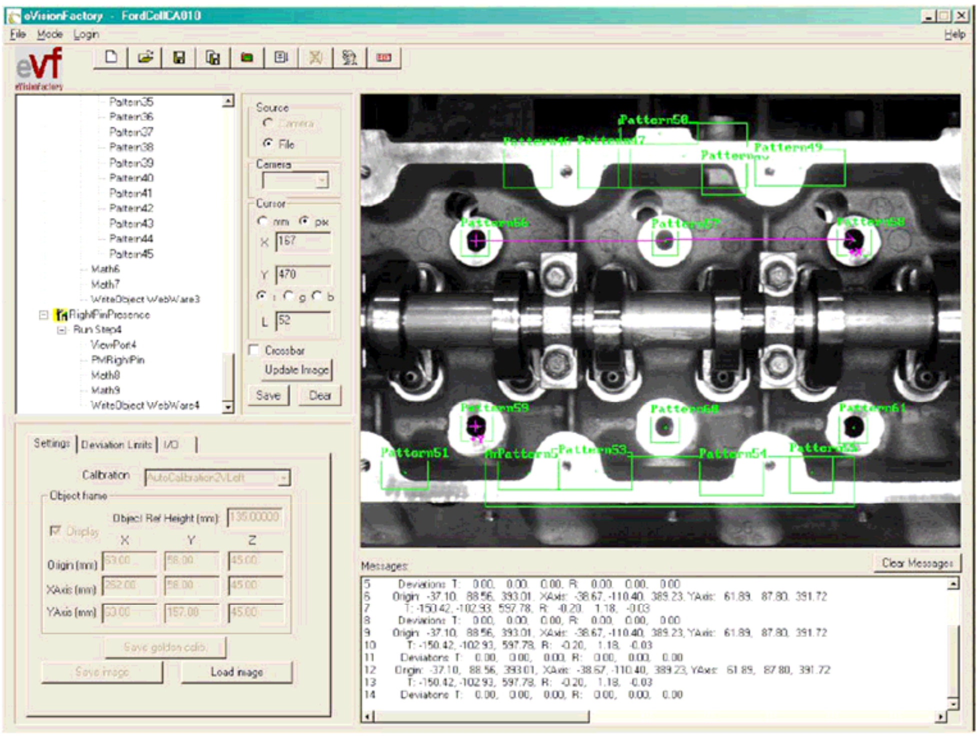


Single Camera 3DTM (SC3DTM)

A novel technology for guidance of industrial robots in three-dimensional space

Requirements

- Parts must be stationary
- No part overlap
- 10 unique features visible to the camera
- Part to part variation in the position of features must be minimal
- Field of view must contain all features
- Camera resolution must be less than 10% of the accuracy/repeatability required by the application



Summary

Machine Vision is:

- ✓Affordable
- ✓Used in many applications
- ✓Convenient
- ✓Easy-to-use
- ✓Saves time
- ✓Safe

Primary Vendors of Technology

3D Systems

- Cohu, Inc., Electronics Division
- LMI Technologies Inc
- SICK IVP AB
- StockerYale Canada
- VITRONIC Machine Vision Ltd.

Cameras

- Adimec
- Basler Vision Technologies
- Daitron
- JAI A/S
- Sony Electronics Inc.

Complete Vision Systems

- Cognex Corporation
- ISRA Vision Systems
- Tordivel AS
- Vitronic Machine Vision

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- http://www.machinevisiononline.org/public/articles/Babak_Habibi_July03.pdf