Advances and Challenges of Computer Vision in Agriculture

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Agricultural Research Organization

The Research Arm of the Ministry of Agriculture

Vision Statement

Excellence in research and development for the promotion of agriculture and the protection of the environment

VOLCANI CENTER – BET DAGAN

RESEARCH CENTER – NEVE YAAR

RESEARCH CENTER – GILAT

PERSONNEL

200 Scientist (PhD)
~390 Research Assistants, Technicians
~140 Administration Staff
~240 Graduate Students
~ 40 Foreign Visiting Trainees

Funding

Government ~ 60%
Competitive granting agencies – 32%
Industry R & D projects – 8%

DIRECTOR

DEPUTY DIRECTOR

ASSOCIATE DIRECTOR

- Soil, Water & Environmental Sciences
- Plant Sciences
- Plant Protection
- Postharvest & Food Sciences
- Animal Sciences
- Agricultural Engineering



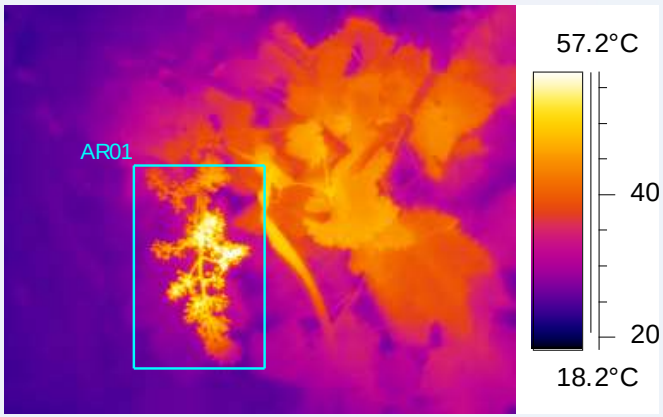


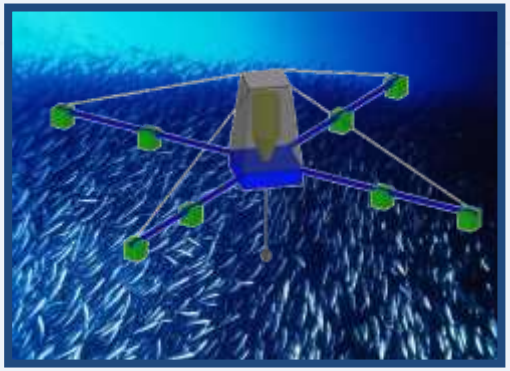

Regional Centers

- Neve Ya'ar
- Gilat


Institute of Agricultural Engineering

- The only research organization in Israel whose activities encompass a wide range of engineering and technological topics relating to **all** aspects of agriculture.
- About 60 people, including 14 research scientists





Improved Efficiency

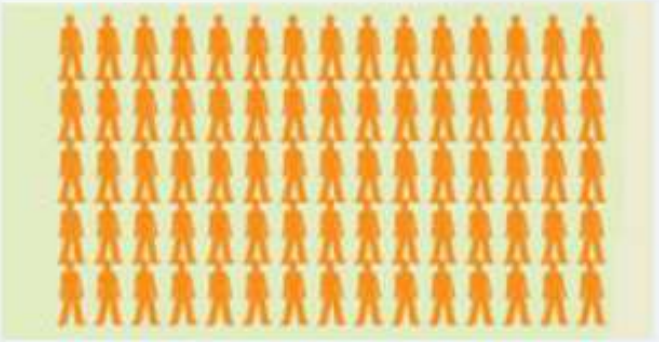
Number of people fed by one farmer

In 1955

15

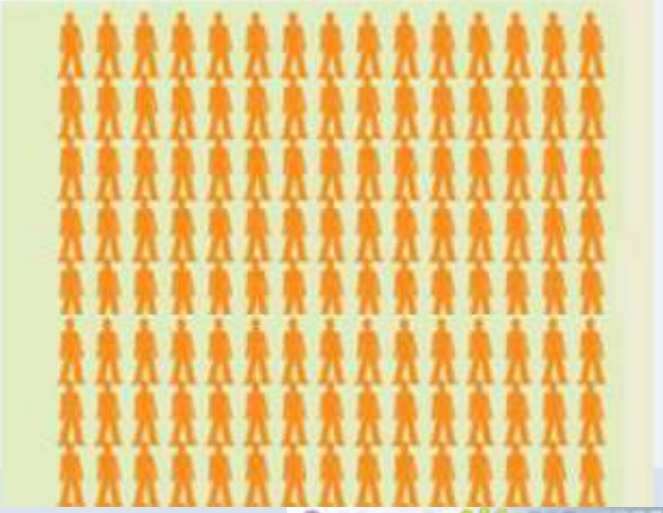
In 2000

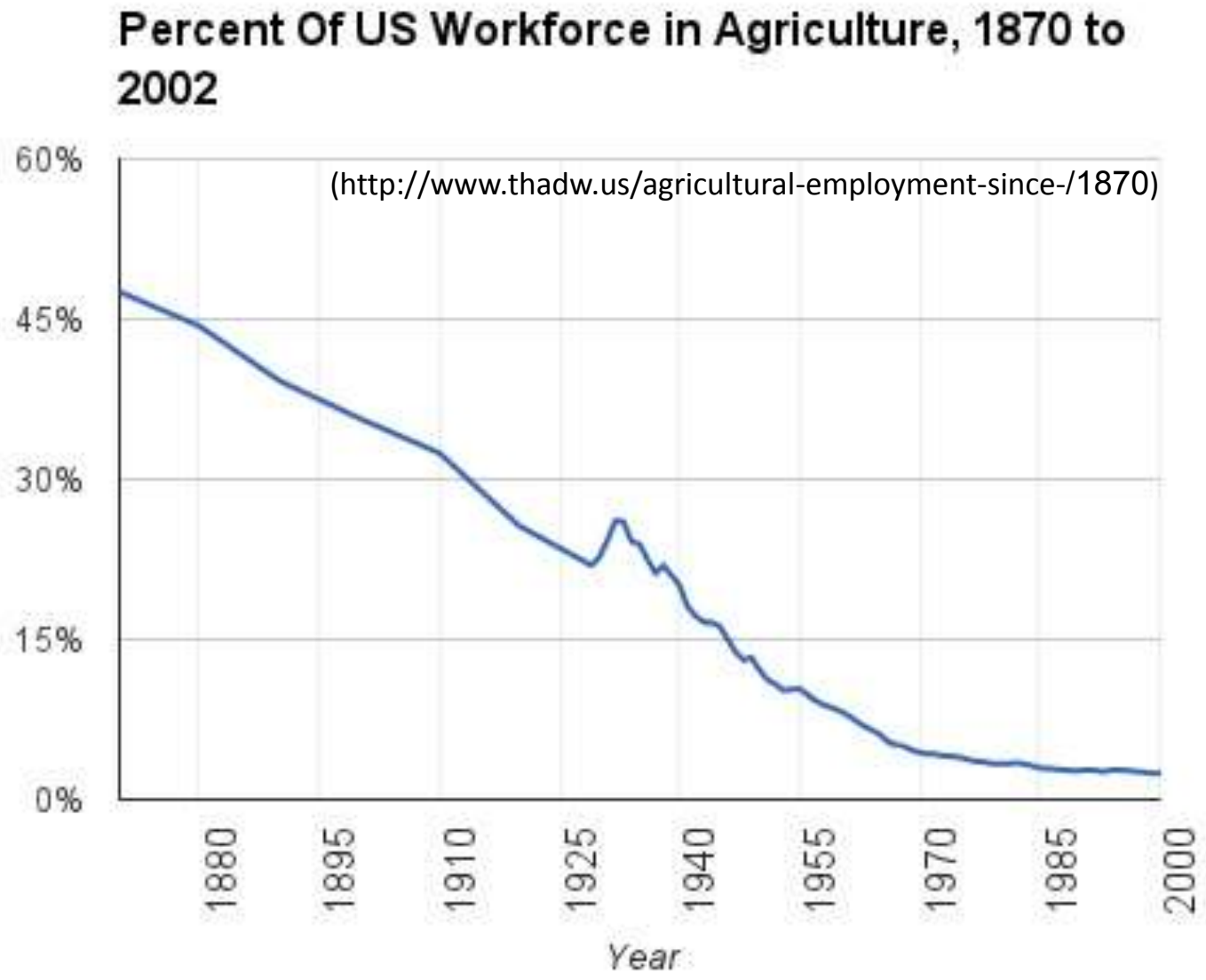
90



In 2015

400




Percent Of US Workforce in Agriculture, 1870 to 2002
(http://www.thadw.us/agricultural-employment-since-/1870)
60%
45%
30%
15%
0%
1880
1895
1910
1925
1940
1955
1970
1985
2000
Year

Evolution of Productivity in Agriculture and Other Sectors

Unstructured Environments

- Unknown a-priori
- Unpredictable
- Dynamic

Unstructured Environments

- The terrain, vegetation, landscape, visibility, illumination and other atmospheric conditions are not well defined; vary, have inherent uncertainty, and generate unpredictable and dynamic situations.

Unstructured Objects

Variable and non-uniform:

size

shape

color

texture

location

	Industry	Space Under-water Military	Medical	Agr.
Env.	+	-	+	-
Objects	+	+	-	-

- Livestock and aquaculture
- Grading and sorting
- Field crops and orchards
- Precision agriculture
- … and many more

… greenhouses

… storage

… consumers

… etc.

Computer vision technology for automated lameness assessment

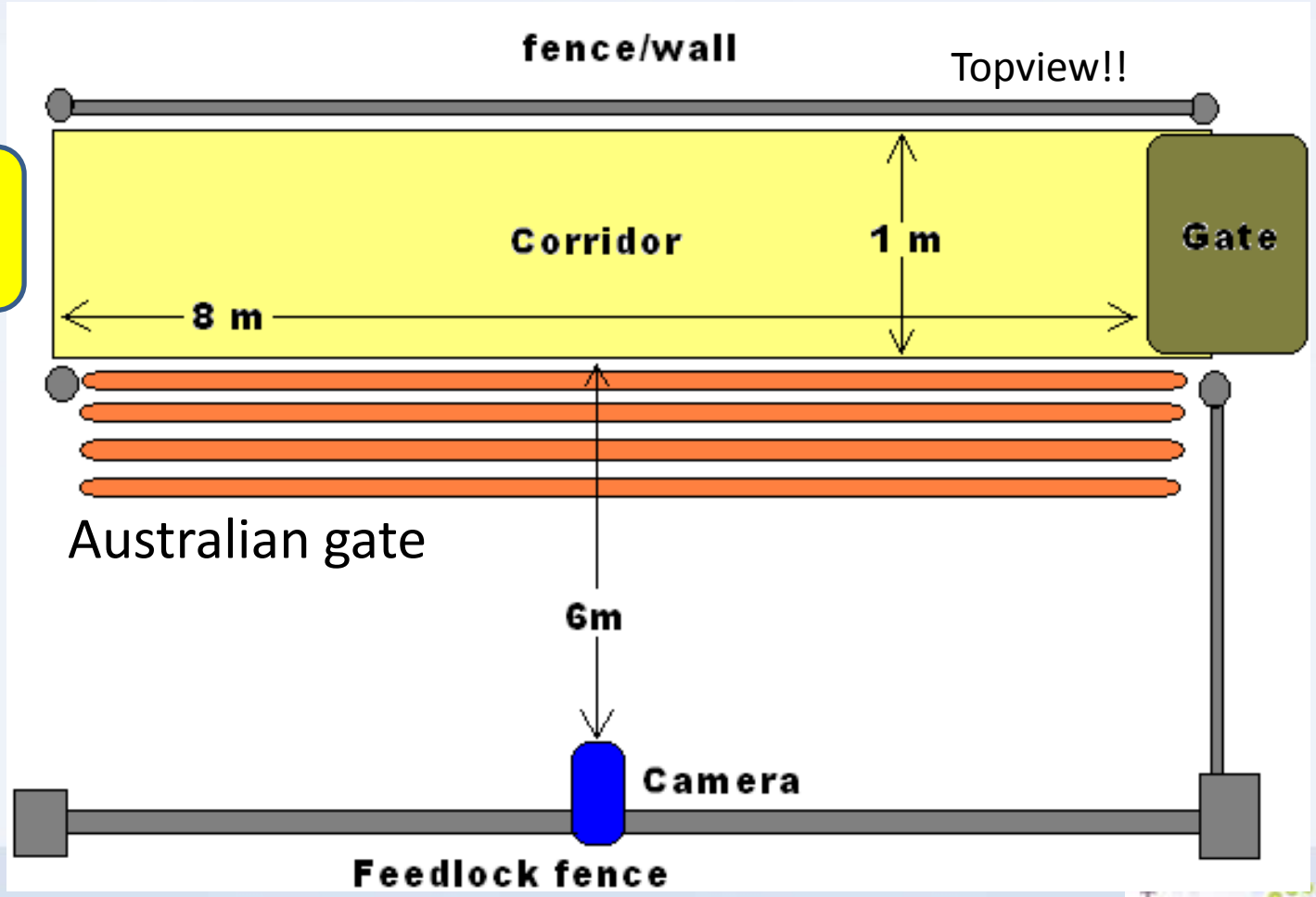
- What is lameness?
  - … deviation in gait and posture due to pain or discomfort resulting from hoof and leg injuries and diseases.

2D RGB computer vision

- Lameness = deviation in gait and posture …
- Recording of cow gait → after milking

Cow shed

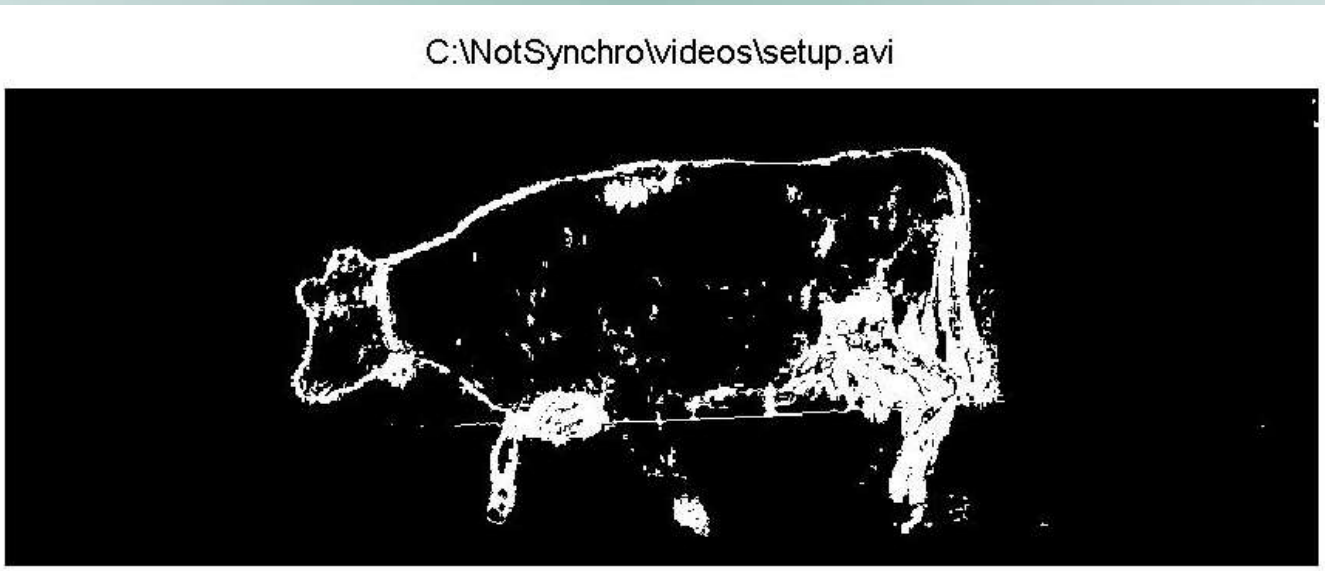
Milking Robot

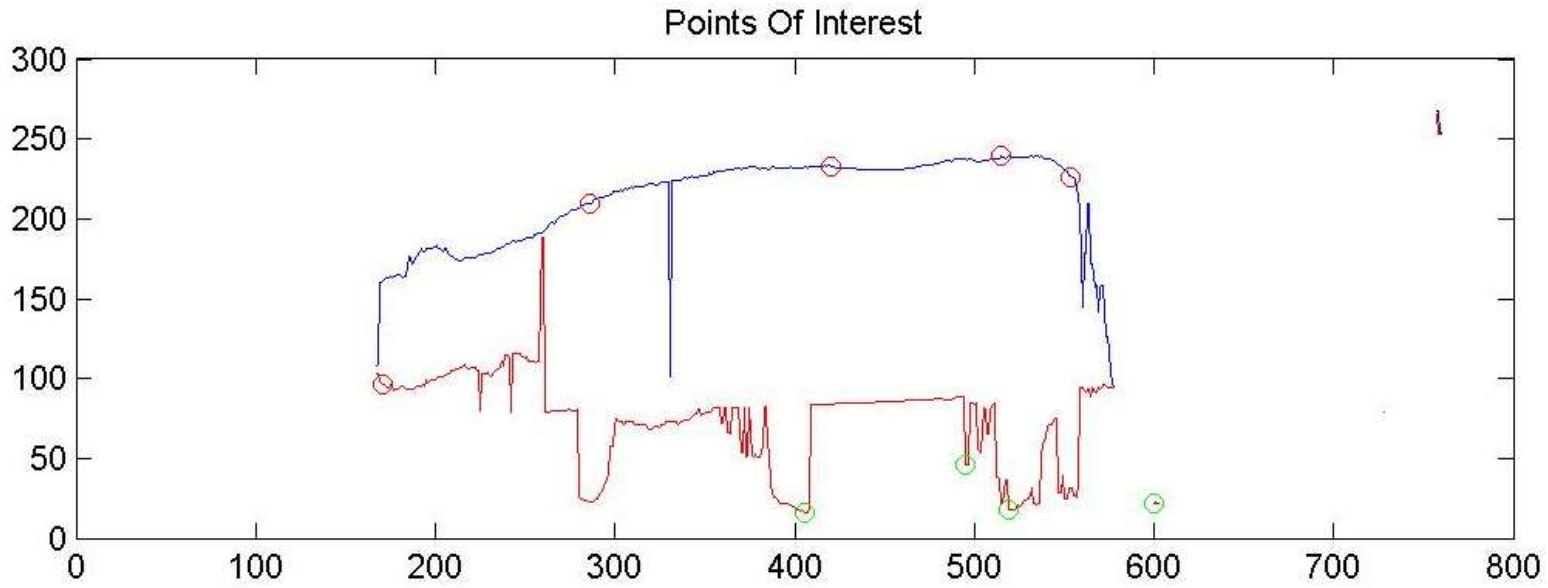


Cow shed

Milking Robot

2D Video preprocessing

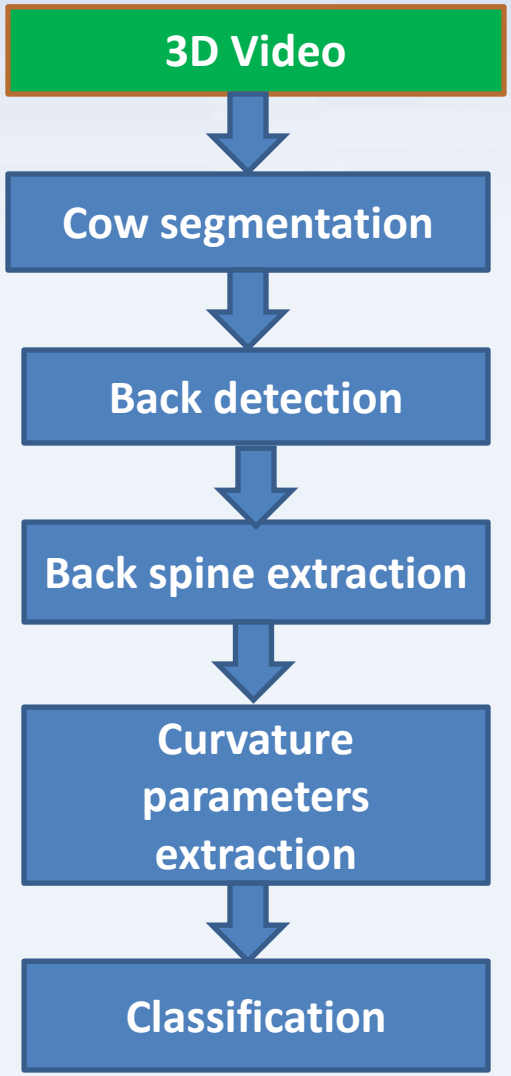


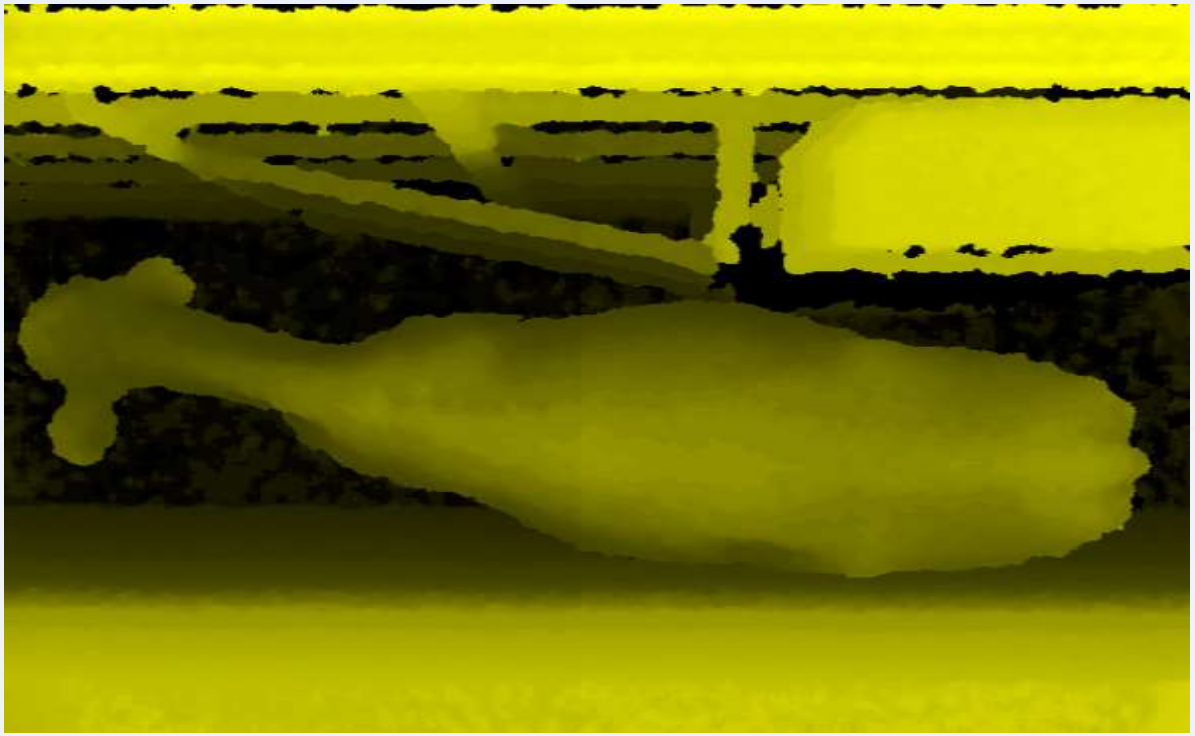


De

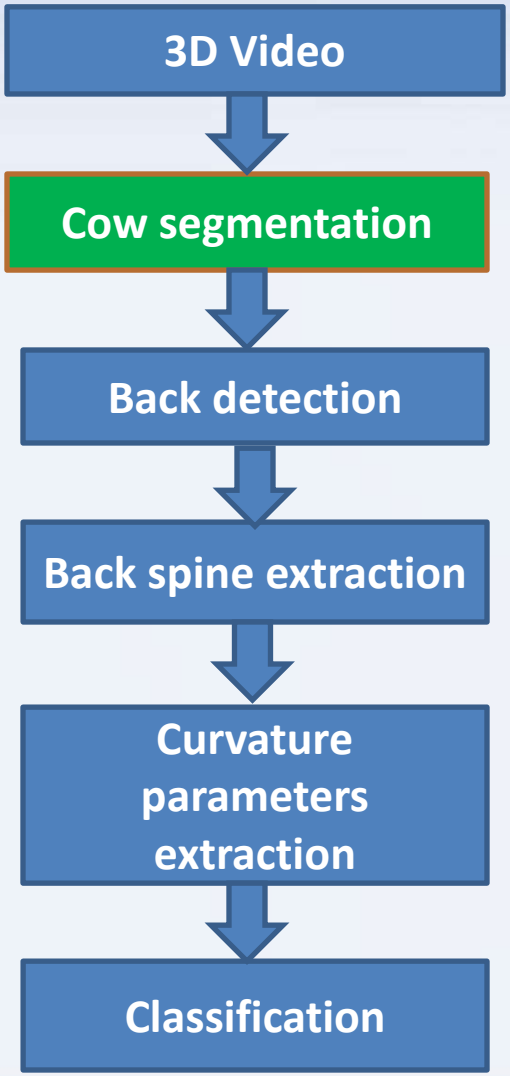
Microsoft Kinect

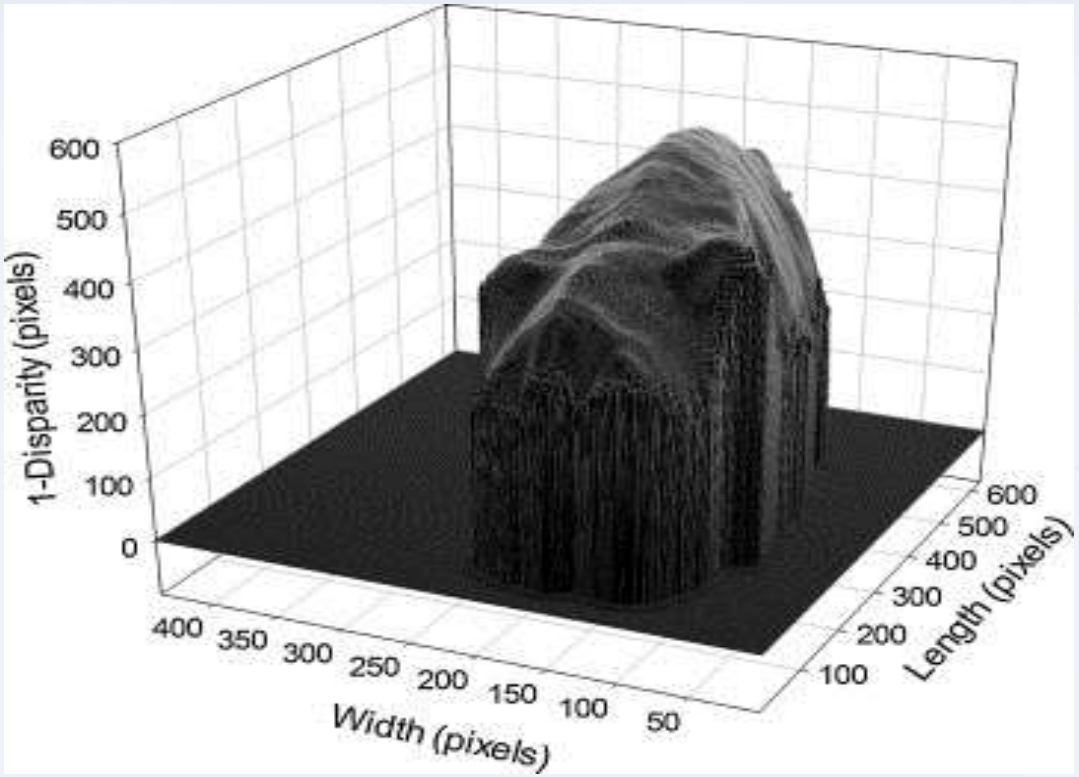
Algorithm flowchart





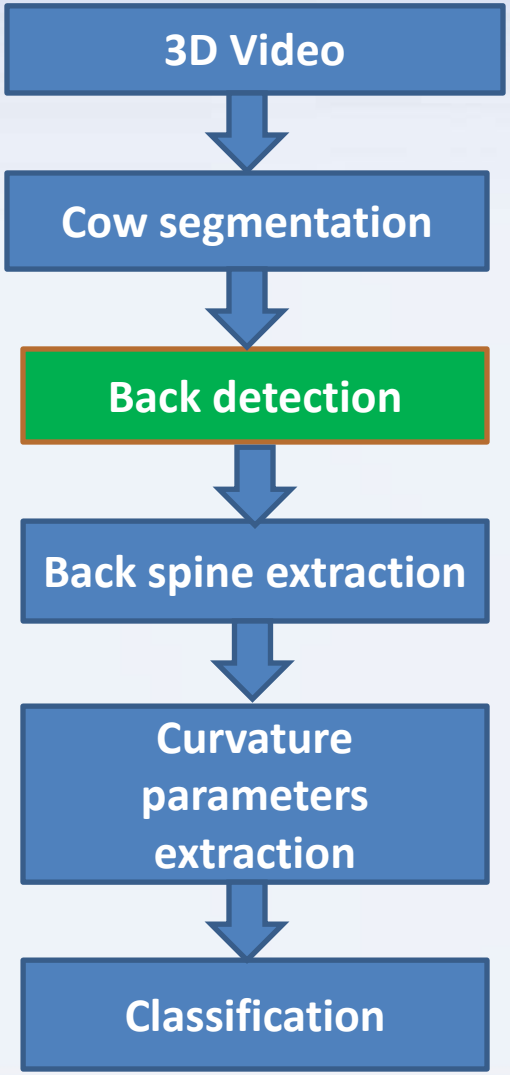
Algorithm flowchart





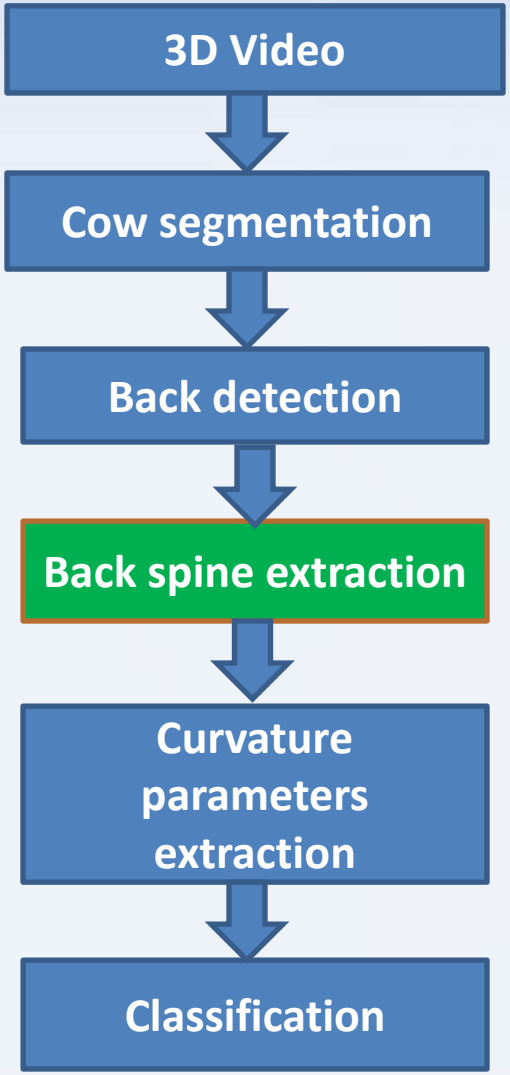
Threshold on depth image

Algorithm flowchart



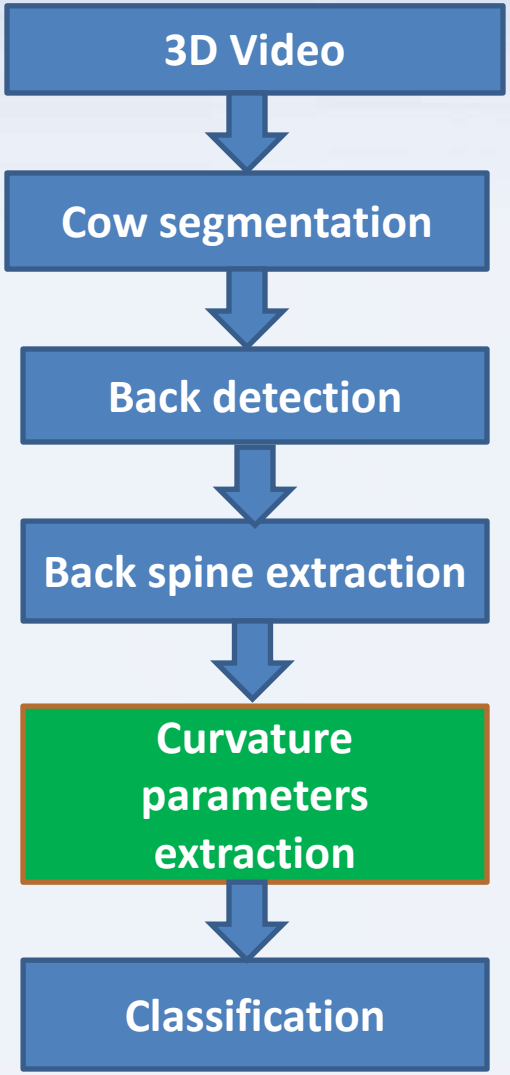
Pixel histogram along x-axis

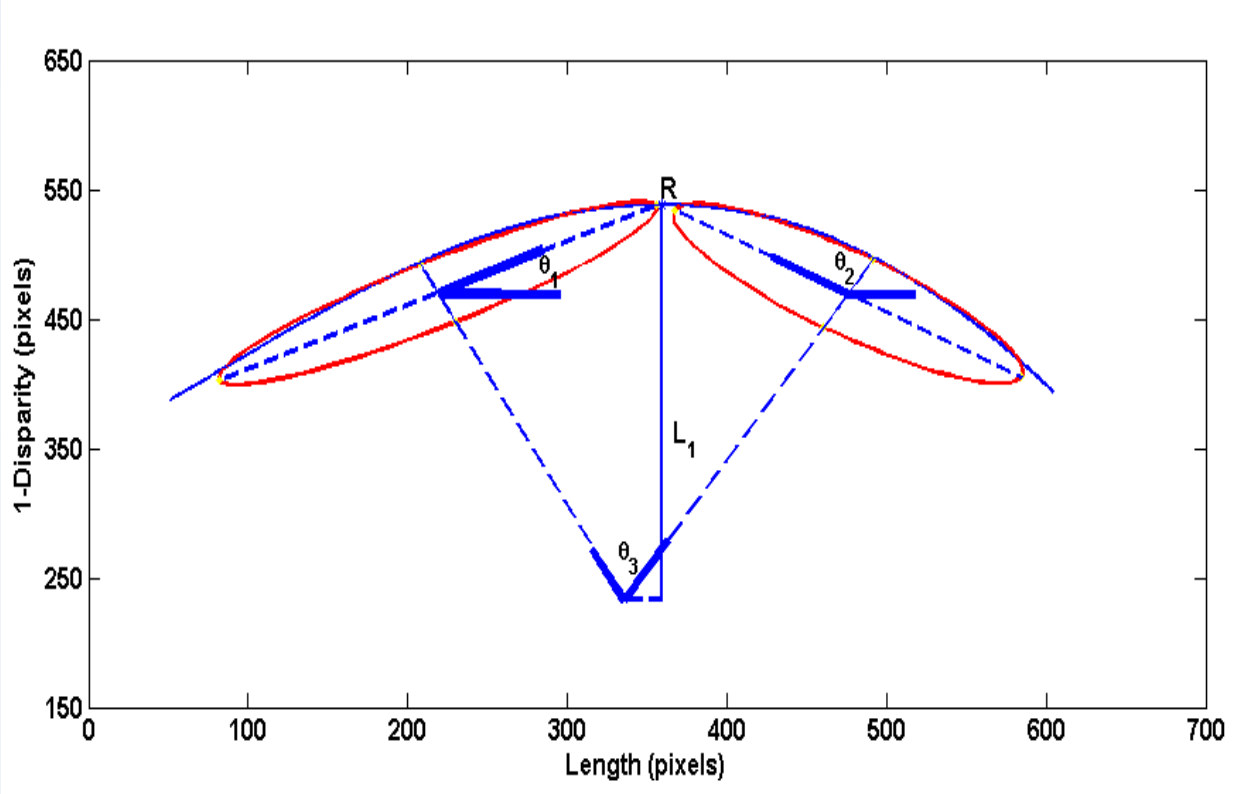
Algorithm flowchart



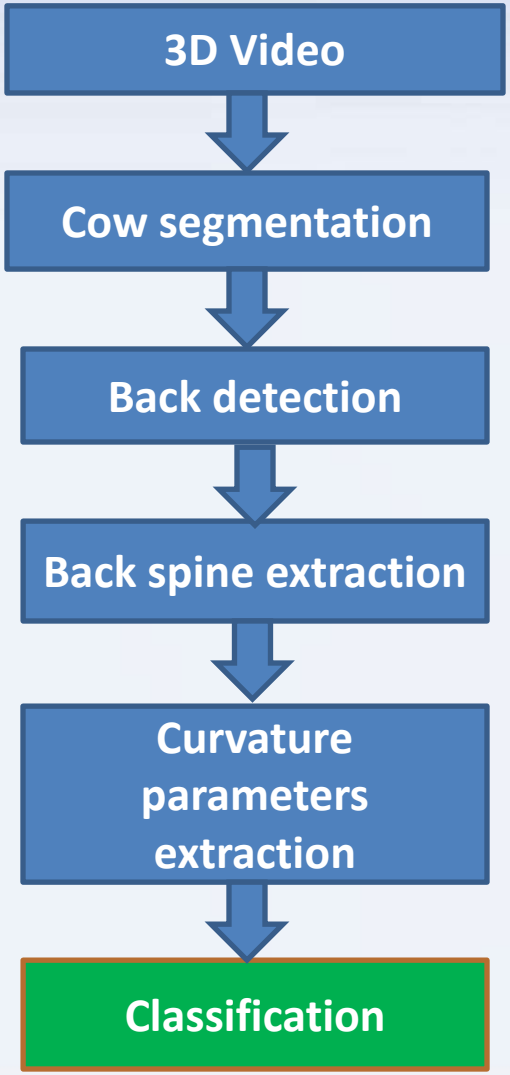
Back spine extraction

Algorithm flowchart

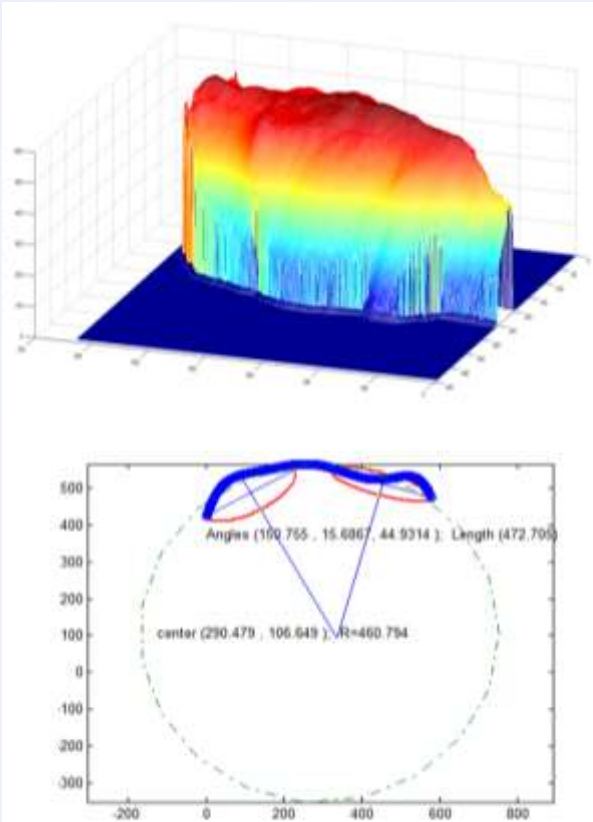




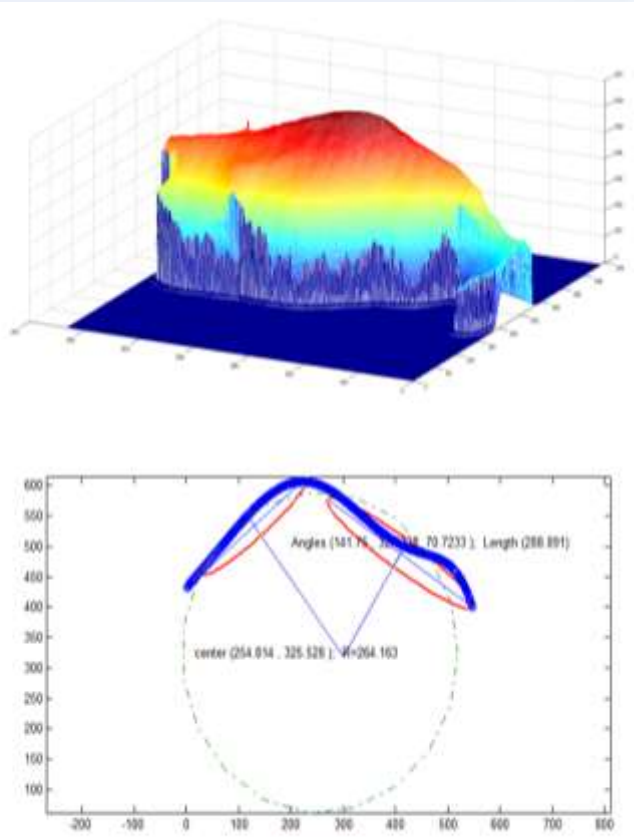
Algorithm flowchart



Not Lame

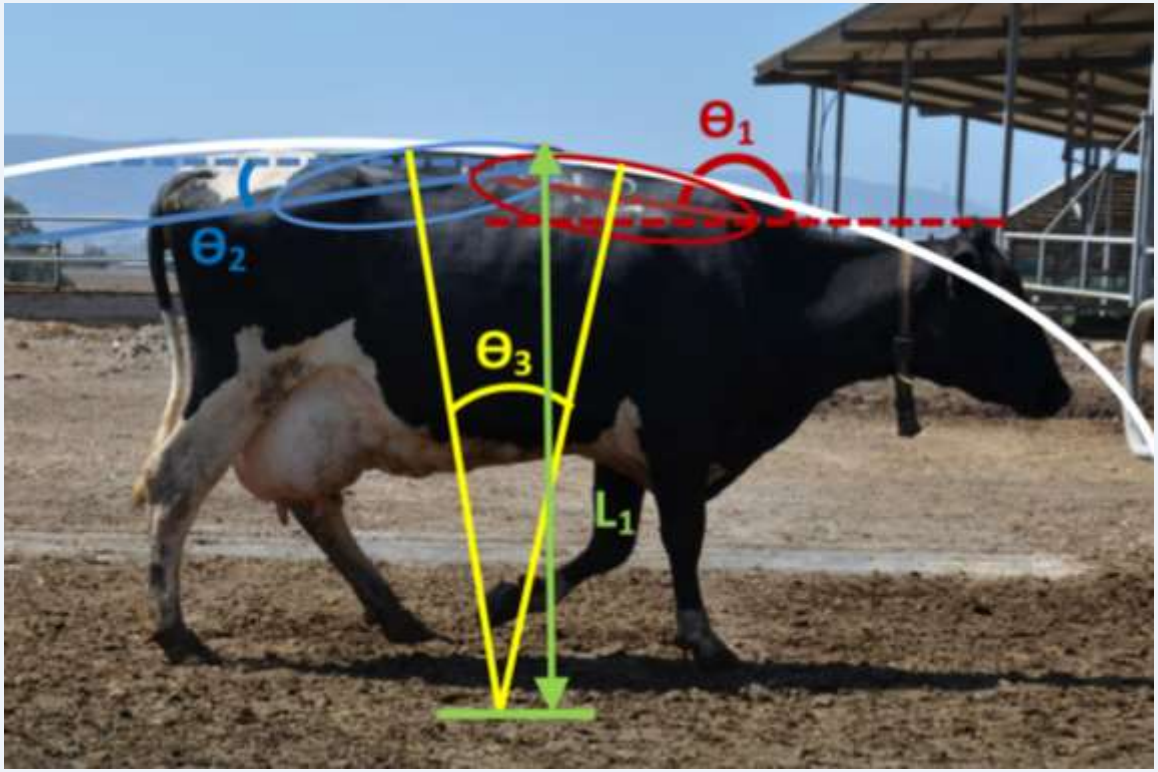


Lame



Algorithm output

- Back Posture Measurement
  BPM



Variables θ1, θ2, θ3 and L1 extracted from the reconstructed back curvature of the cow.

Comparison of a three-dimensional and two-dimensional camera system for automated measurement of back posture in dairy cows

Computers and Electronics in Agriculture Volume 100 2014 139 - 147

Algorithm Verification II

N =	744 (4x186)	Reference Live Score				
		1	2	3	4	5
Model Score	1	46	14	5	1	0
	2	16	50	15	5	1
	3	1	6	9	3	2
	4	0	2	2	4	0
	5	0	0	0	0	4

90.9%

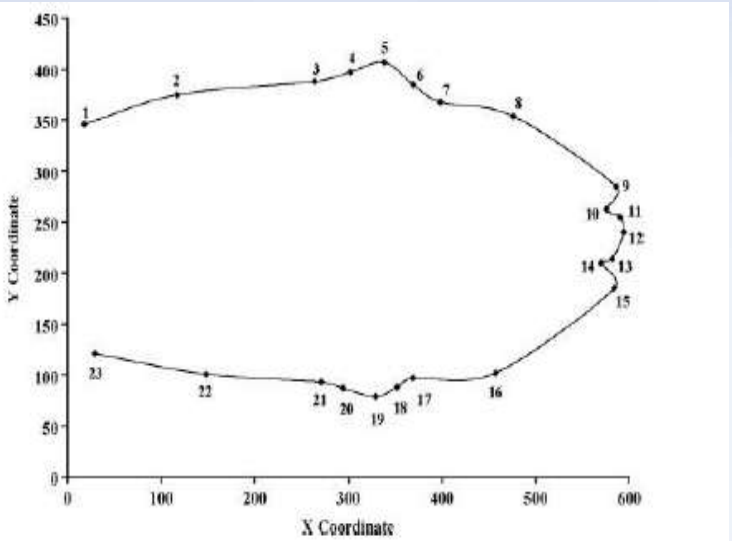
60.8%

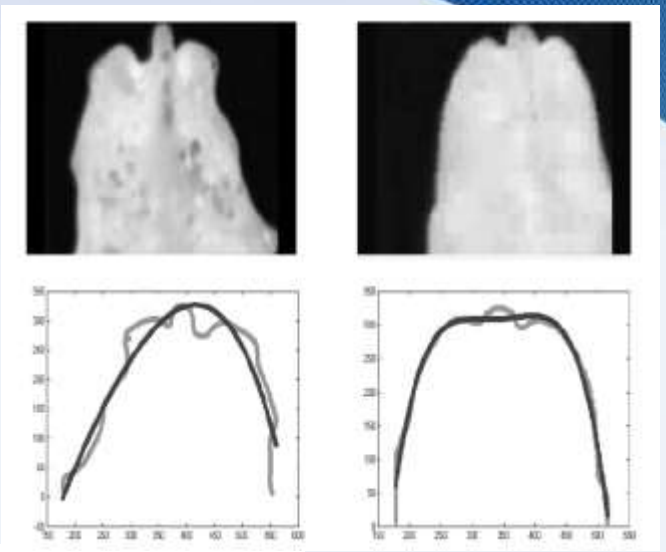
Automatic body condition scoring

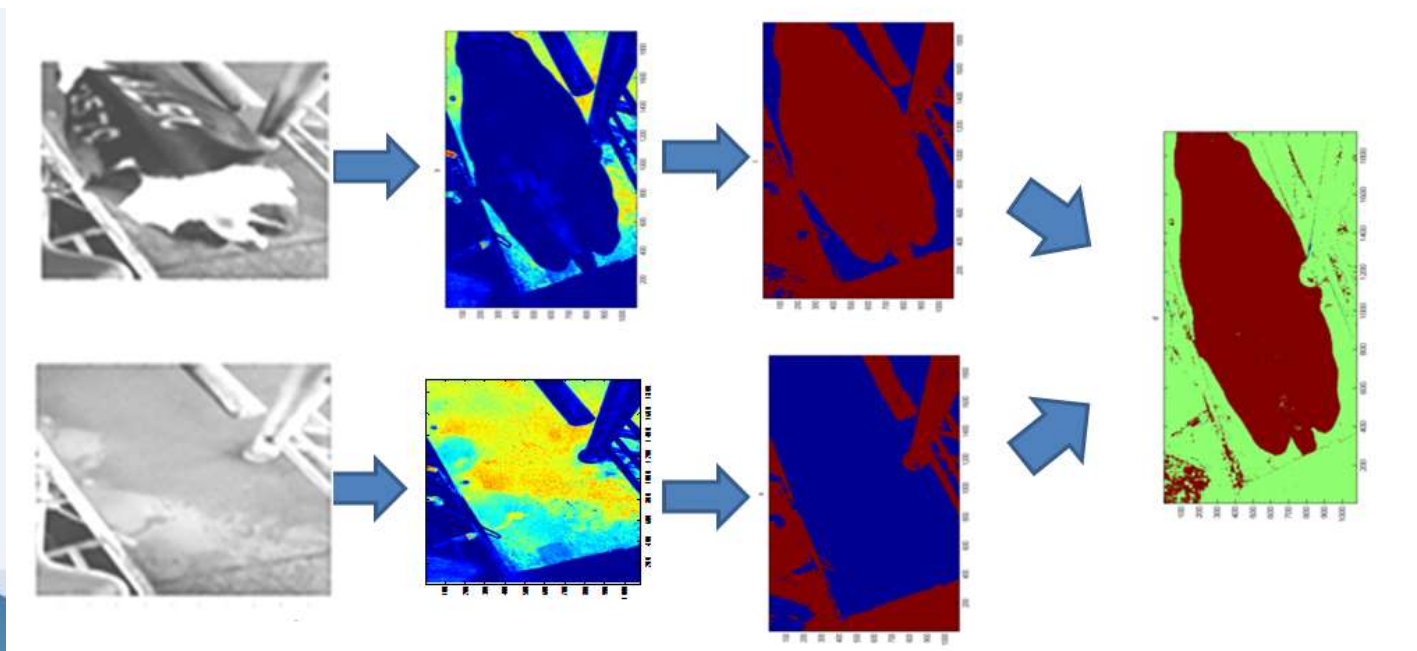
The Problem

- Manual
  - Hard work
  - Labor & Time consuming
- Subjective
  - Technician
  - Previously seen cows

Machine Vision



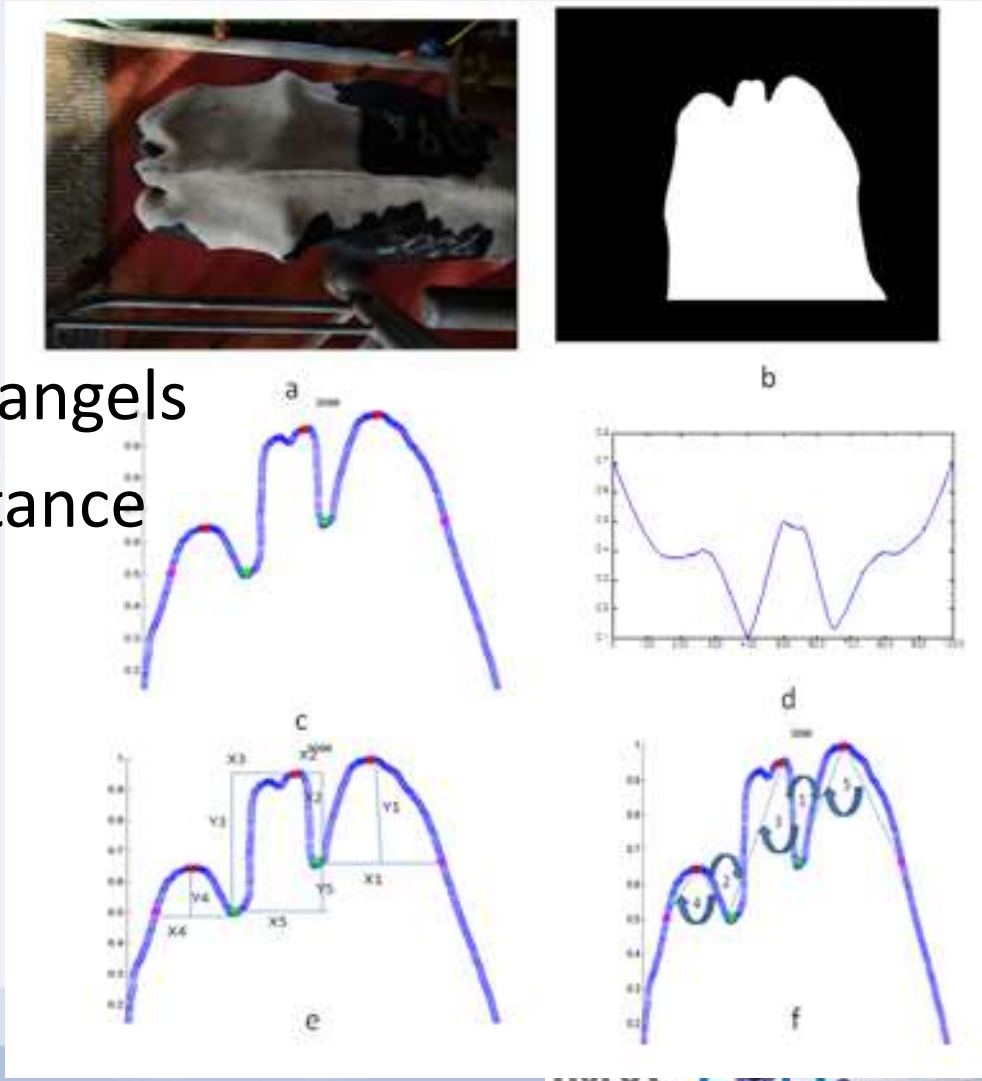




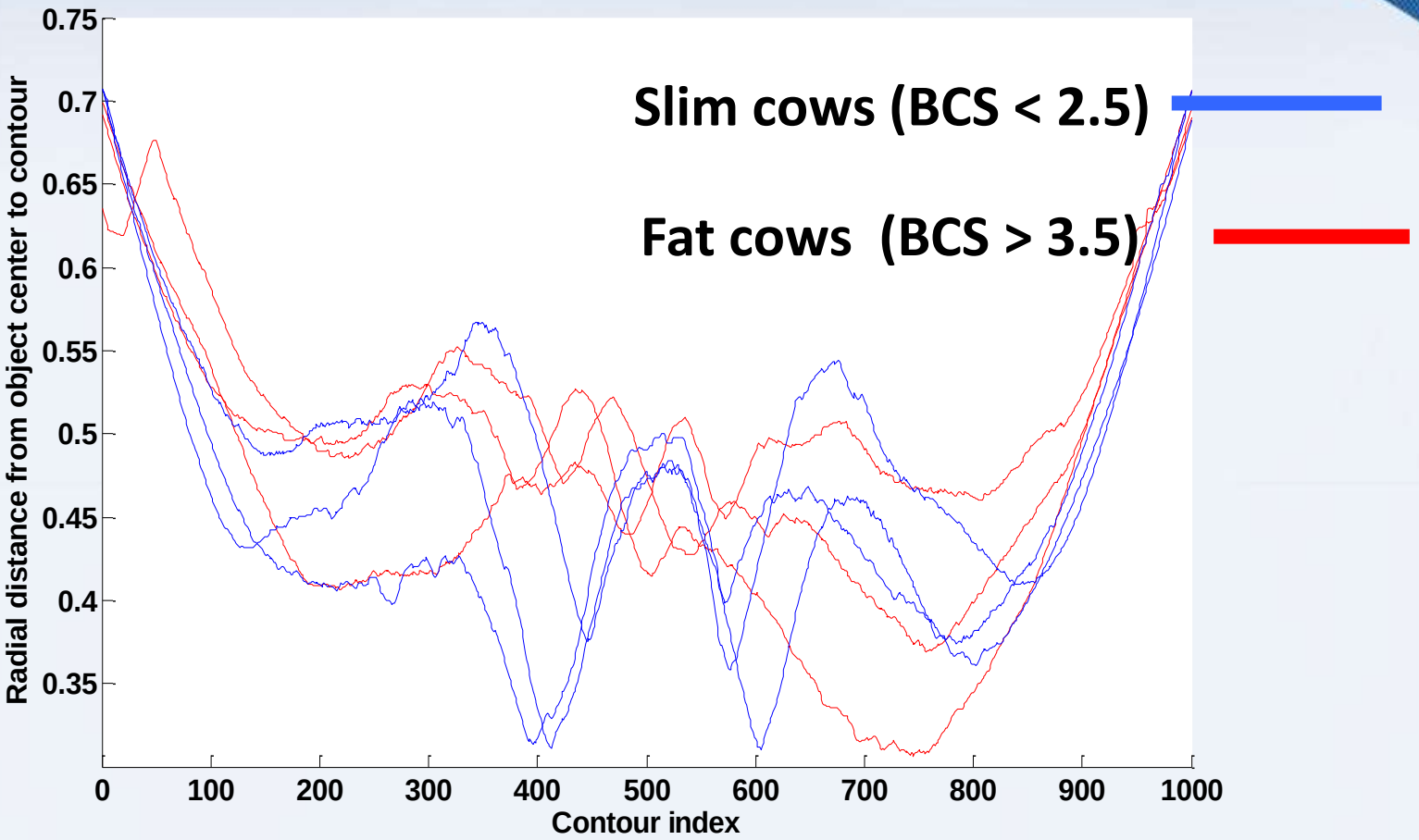
Machine Vision

Cow contour:

- Interpolation 1000 points
- Scaling to 0-1 range
- 5 anatomical points and 5 angels
- Horizontal and vertical distance
- 1 dimension curve
- PCA Analysis
- Fast Fourier transform



Fourier descriptors



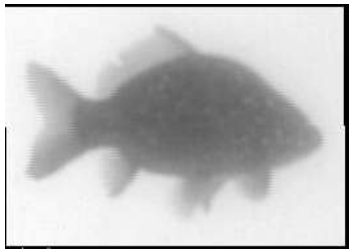
Bercovich, Maltz et al., Halachmi, I
Journal of Dairy Science. 2013 ; 96(12):8047-59

DEVELOPMENT OF A SELECTIVE FISH HARVESTING SYSTEM FOR PONDS

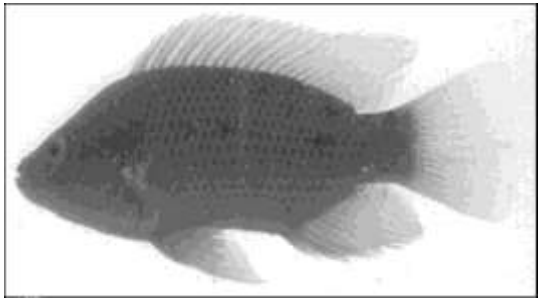
OBJECTIVE

To develop a system for continuous, automatic and selective live fish harvesting in ponds

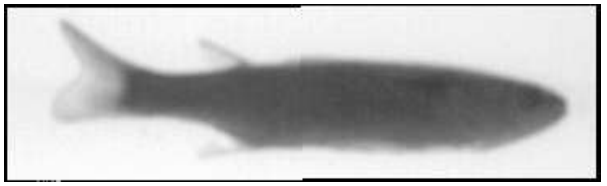
carp

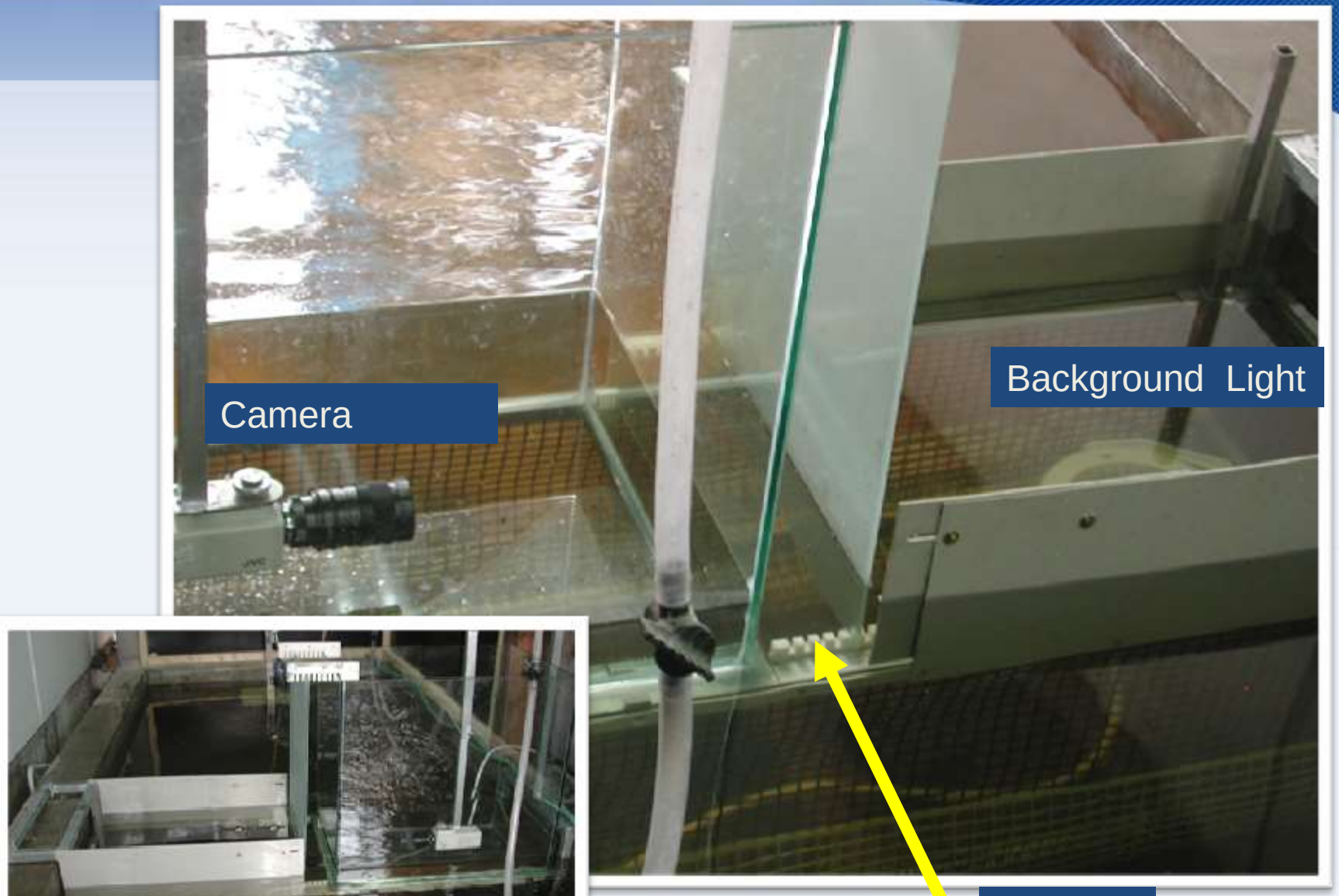


St. Peter's

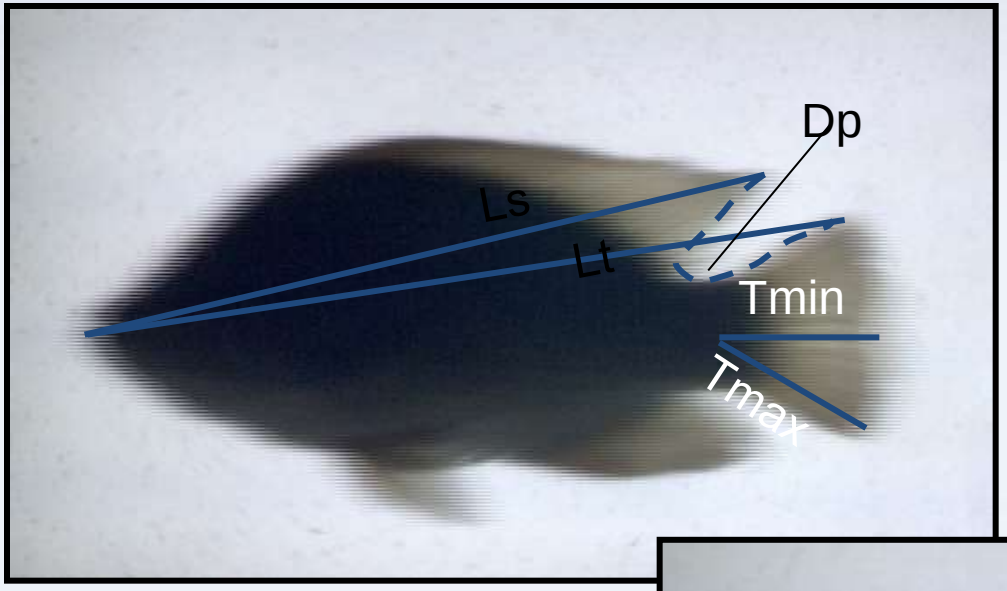


grey mullet




Camera
Background Light
Passage

Geometric Features Extraction



(Lt-Ls)/Lt~ 0.1

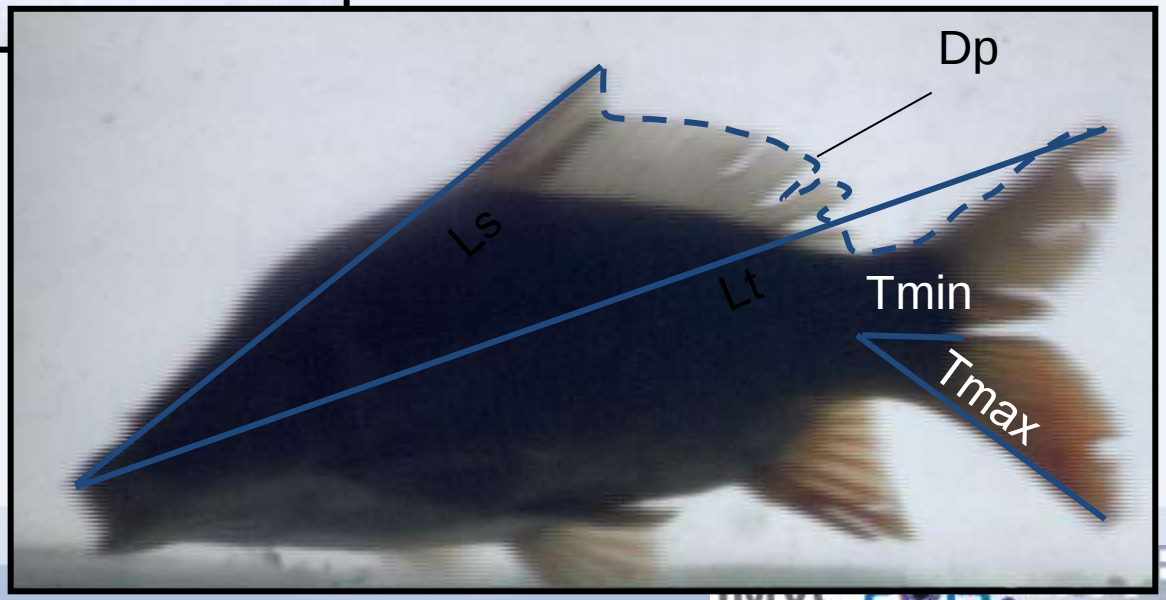
(Lt-Ls)/Dp<0.5

Tmin/Tmax ~ 1

(Lt-Ls)/Lt~ 0.4

(Lt-Ls)/Dp>0.5

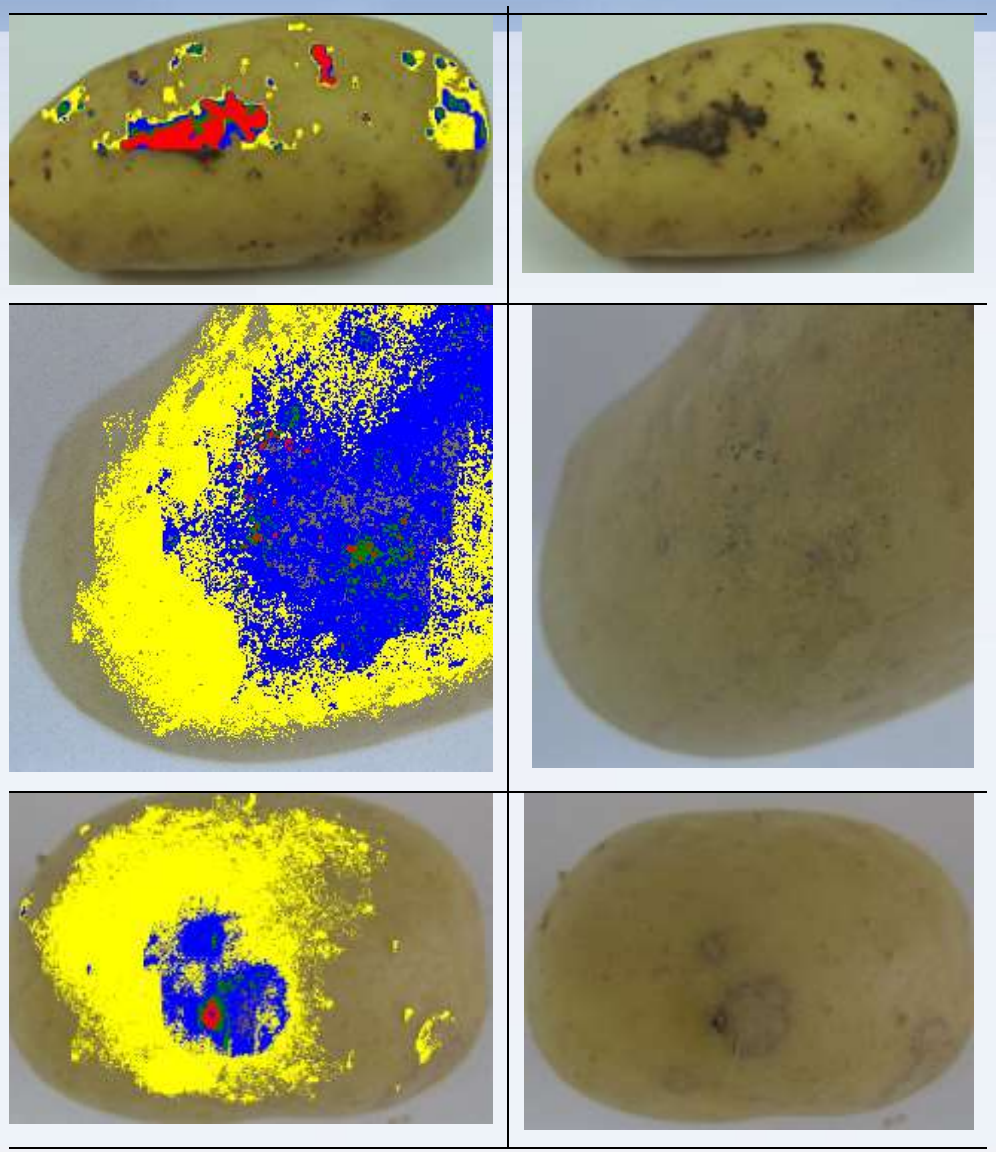
Tmin/Tmax < 1



Ornamental fish

Counting of fishlets

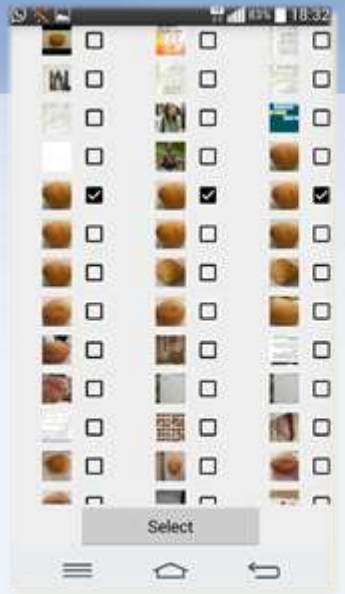
Counting of fishlets



Quality evaluation

Detection of diseases in potatoes

Guy Shani, Lea Tsror, Victor Alchanatis, 2014

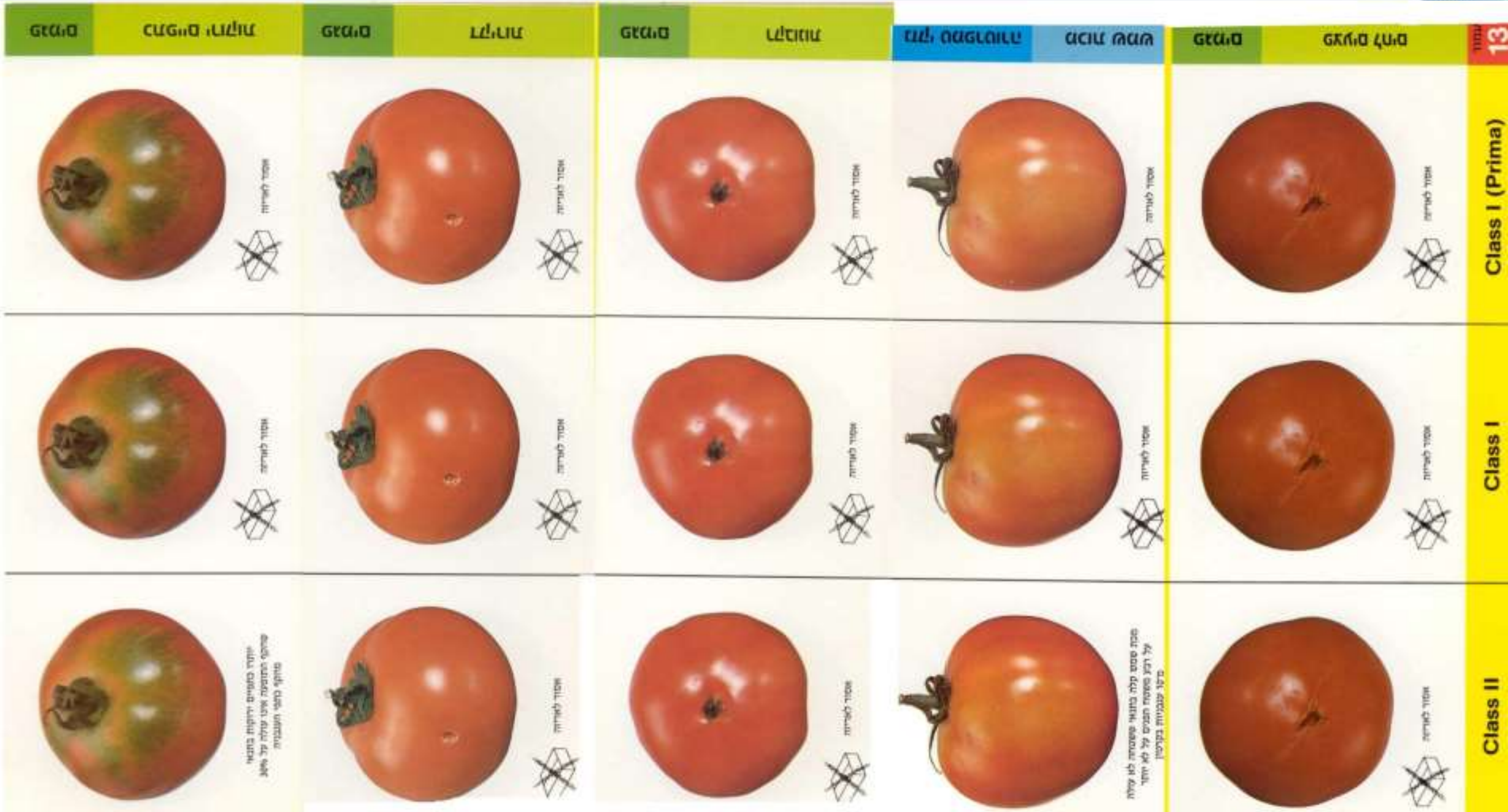


Application for mobile phone

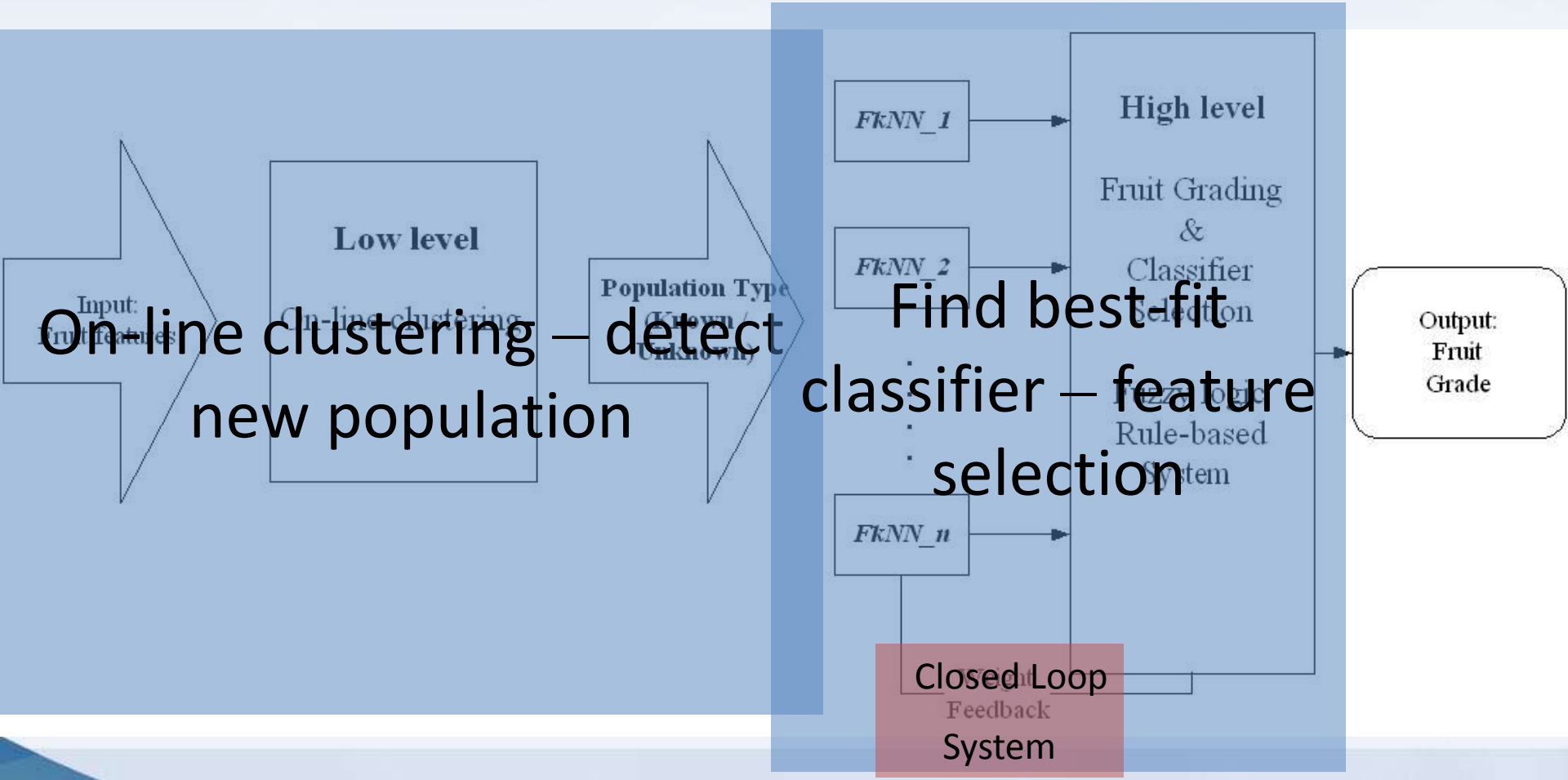
Detection of diseases in potatoes

Agricultural produce classification

Tomatoes Defects



On-line adaptive classifier



On-line clustering – detect new population

Find best-fit classifier – feature selection

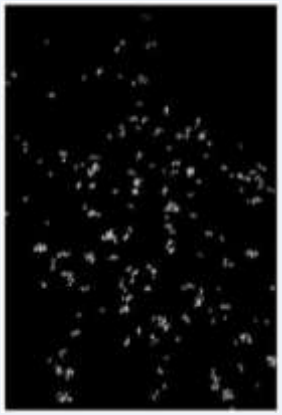
Pattern Recognition, 2012. 45 (7), pp. 2843-2853

Evaluation of apple flowering intensity using color image processing for tree specific thinning

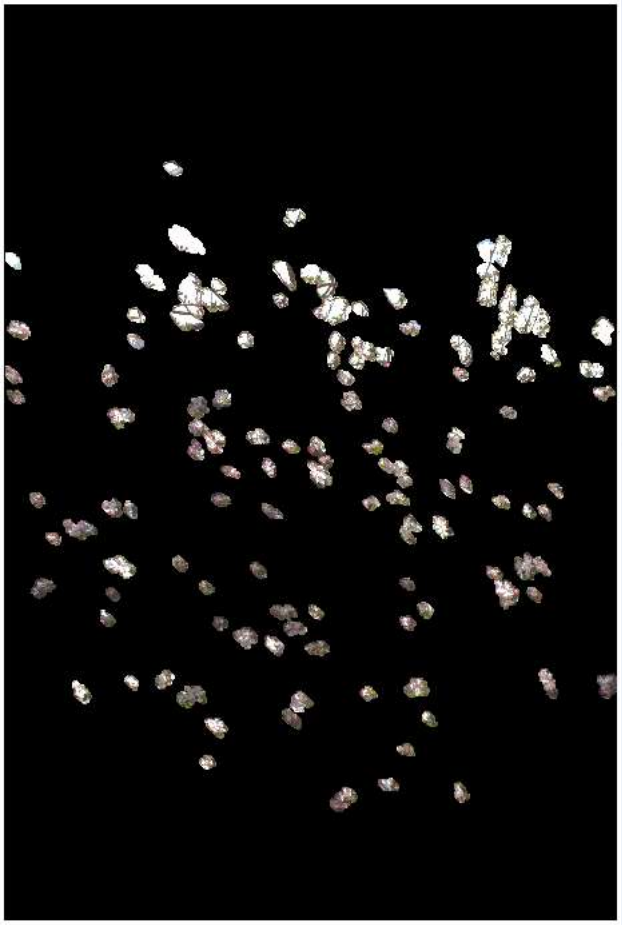
The process..

Process for buds

Process for flowers

Original picture	Thresholding	Geometrical	Zoom in on mask
			
			

Clouds



Autonomous greenhouse sprayer

[redacted]amar
[redacted]elsht

[redacted]

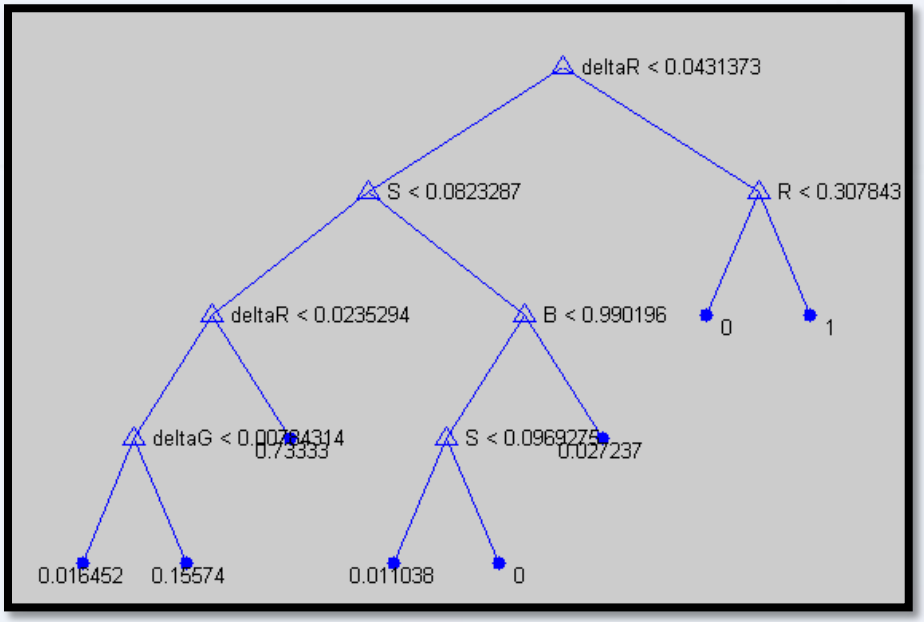
Decision Tree - CART Breiman et al., 1984

- For all features

  Find feature threshold value that maximizes the *"splitting criterion"*

- Among all features

  Choose the one that maximizes the *"splitting criterion"*



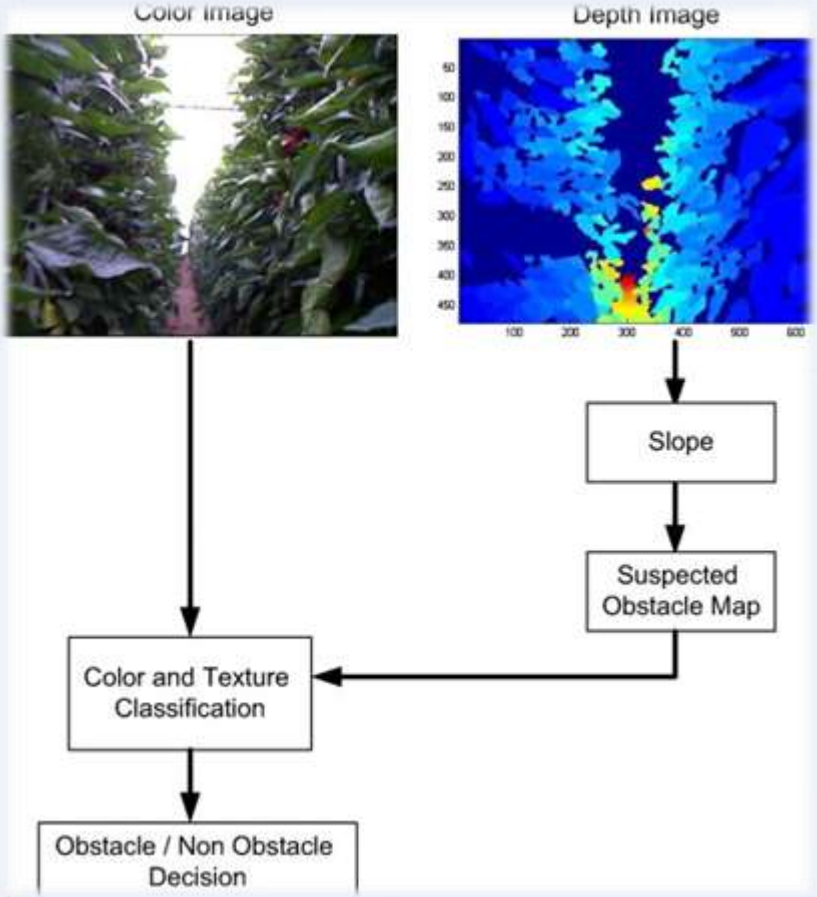
Judges Vote (~ Majority rule)

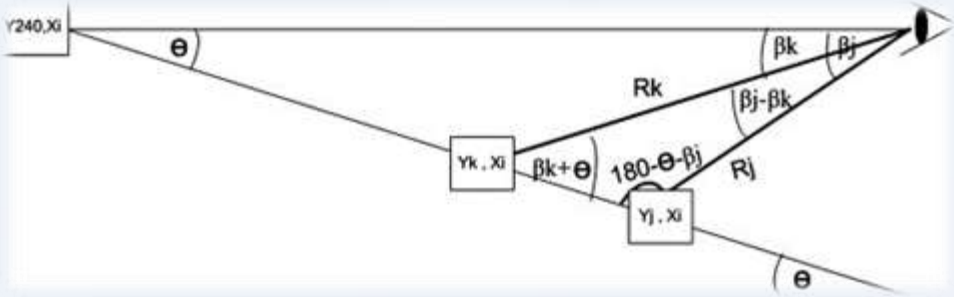
- A customized CART variation, developed in this research
- A *"Judge"* is single level CART (root node only)
- Classification rule:

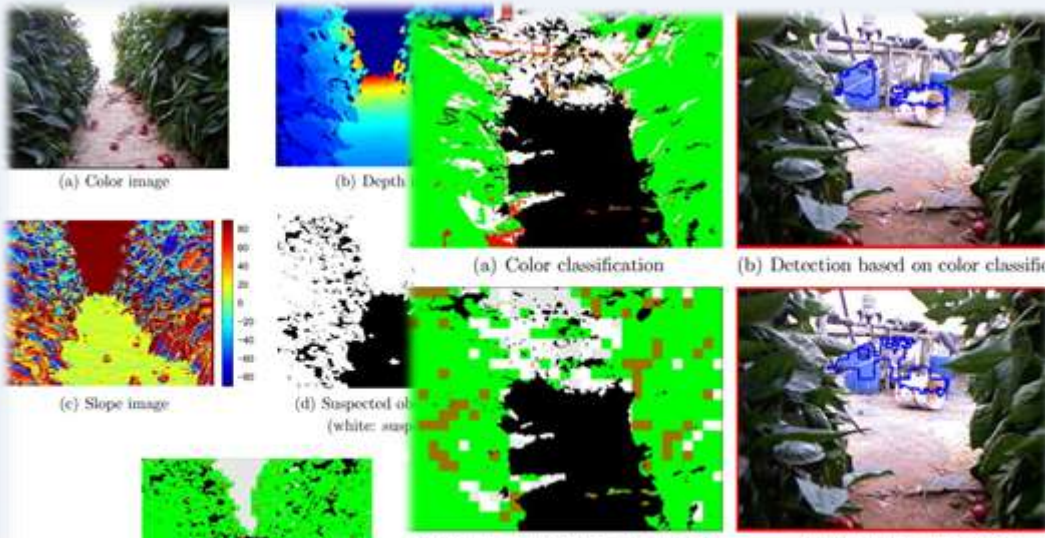
$$\frac{Judges\_Vote}{Number\_of\_Judges}$$

Vote (M)	1	2	1	2	3	1	2	3	4	1	2	3	4	5
Judges (N)	2	2	3	3	3	4	4	4	4	5	5	5	5	5

Obstacle detection in a greenhouse environment using the Kinect sensor







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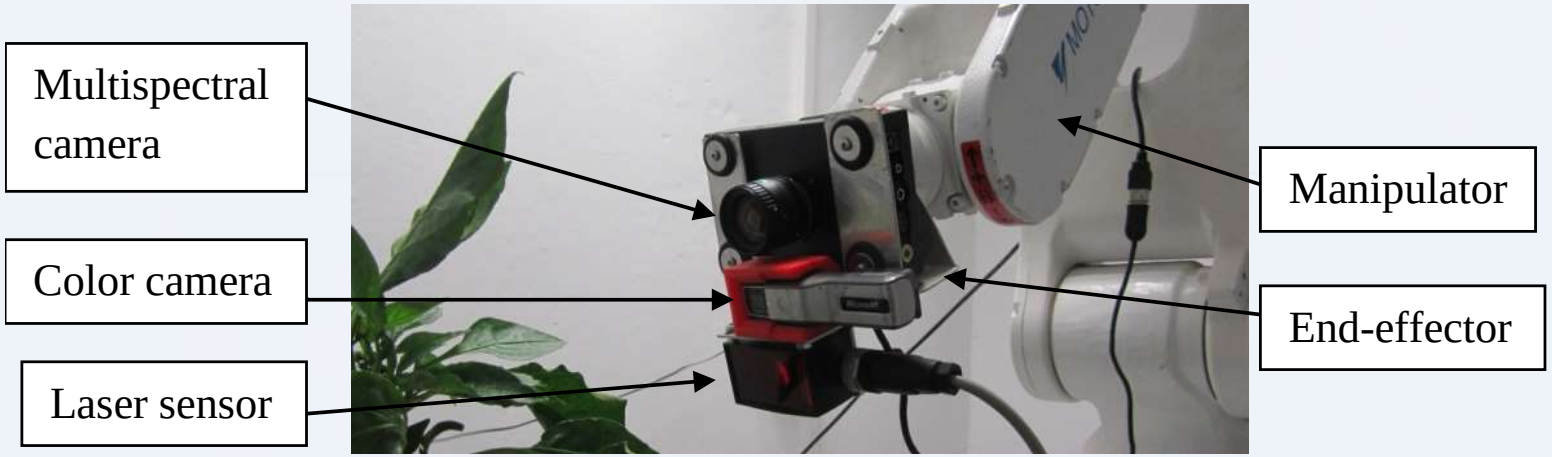
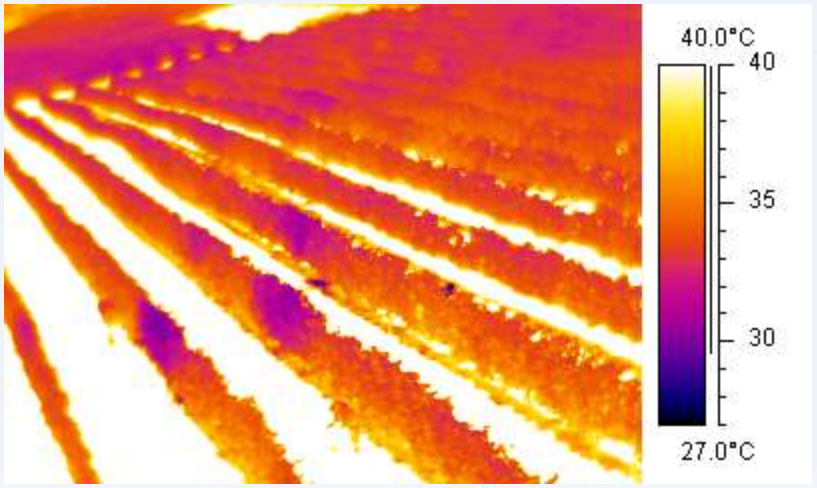
IMVC 2015

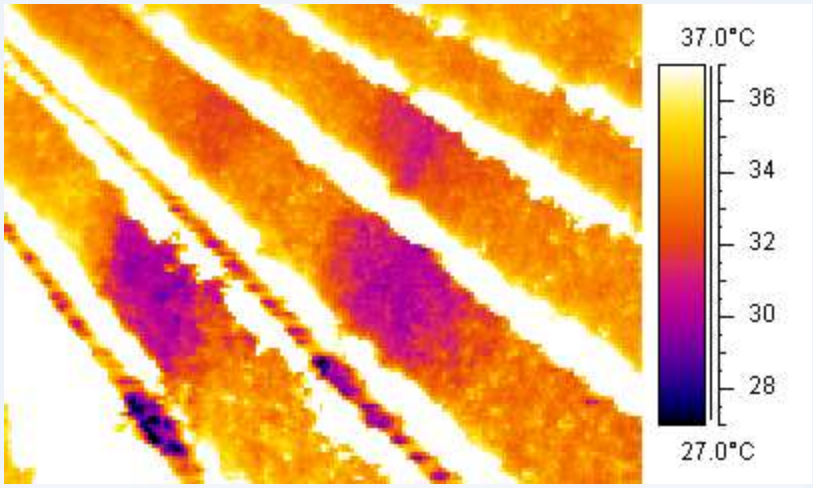
Apparatus

- A robotic manipulator (MH5L, Motoman).
- A custom-made end-effector.
- Sensory apparatus.



Precision agriculture and remote sensing



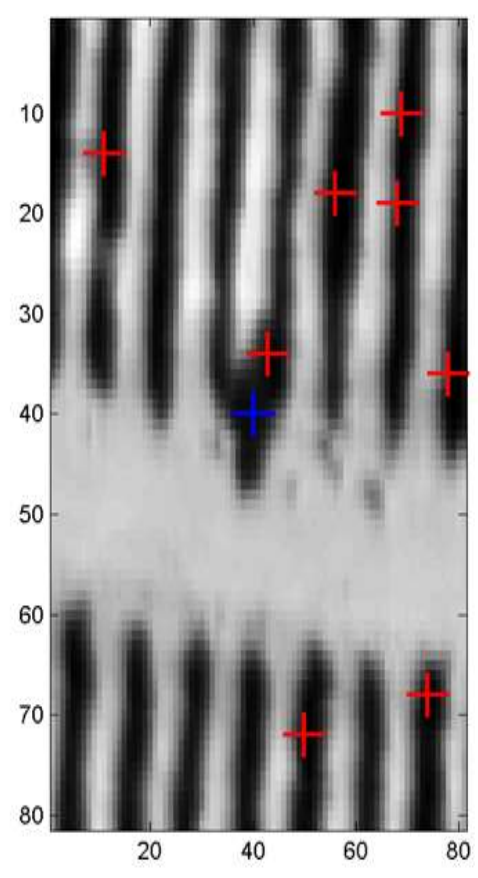


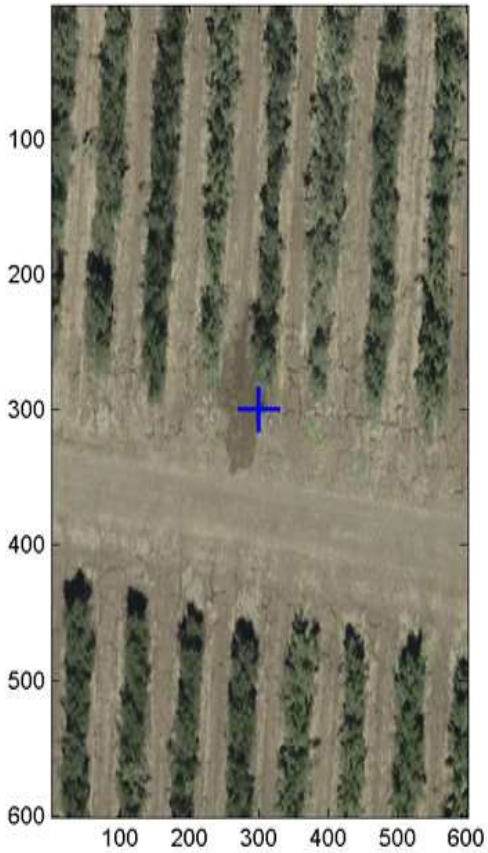
Leach in drippers…

Vineyard, Upper Galilee, summer 2005

Automatic leak detection

- Blue cross shows correctly detected leak.
- Red crosses mark other areas suspected for leaks



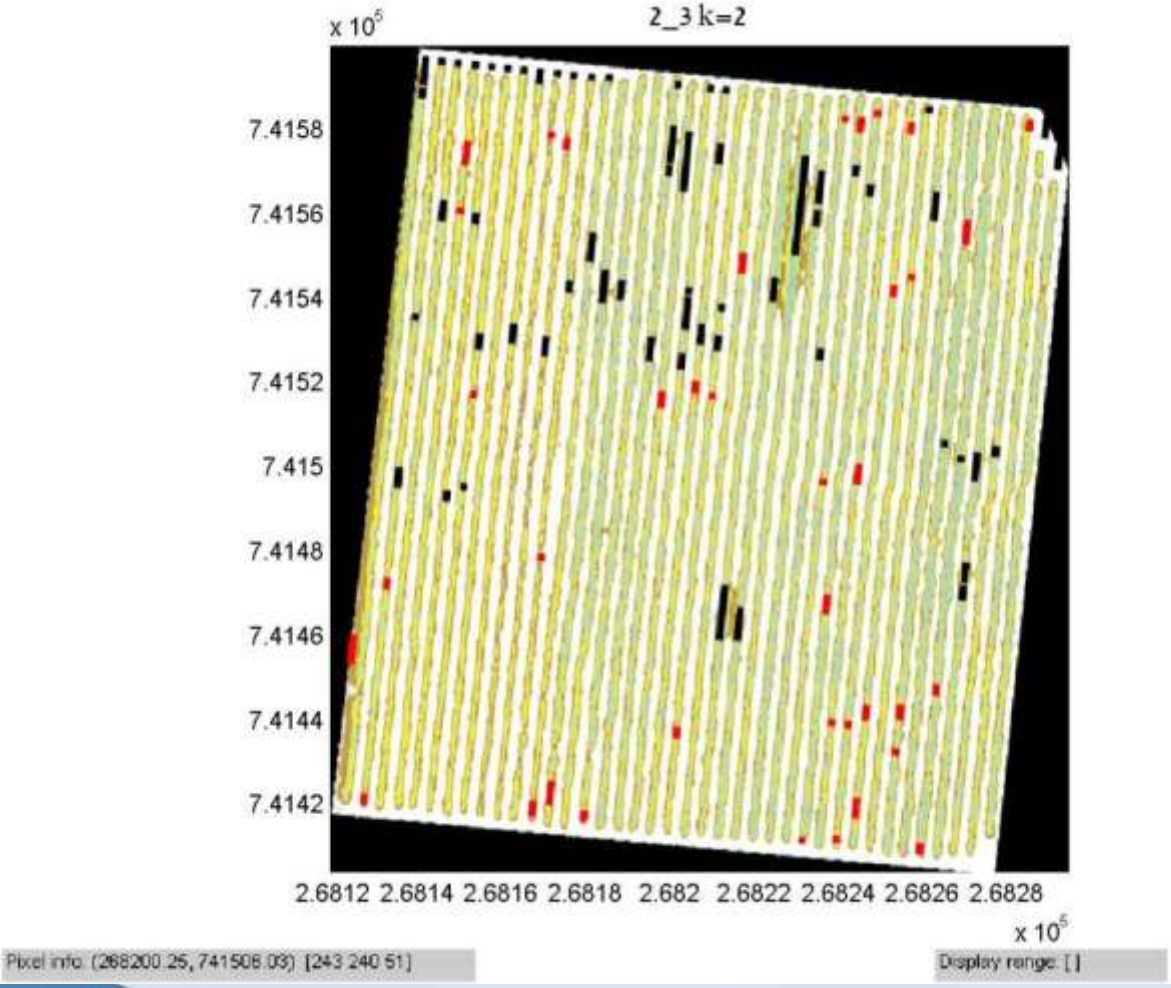


Irrigation malfunctions – ground truthing

Irrigation malfunctions – ground truthing

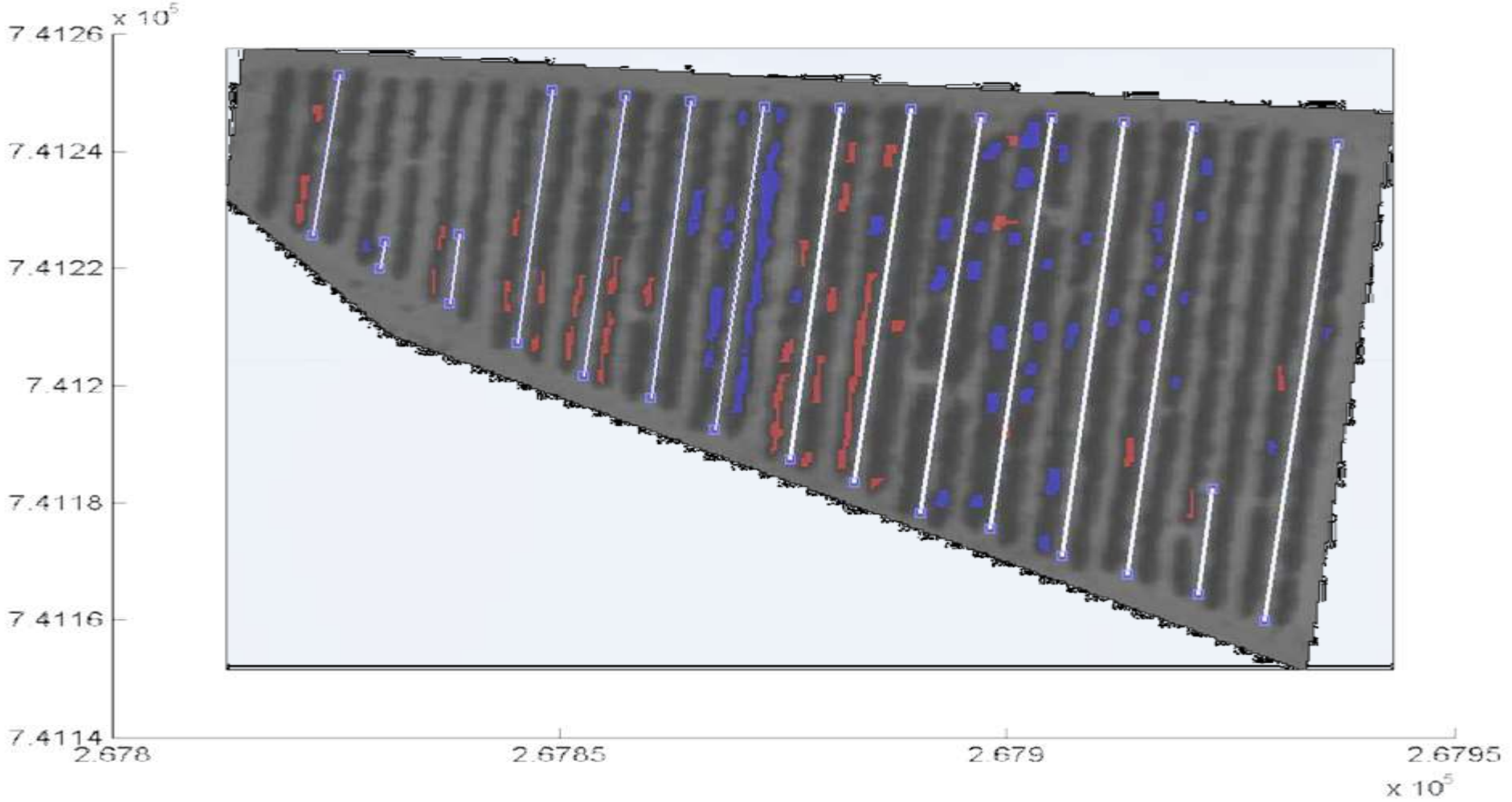
Data from scouting

Automatic recognition

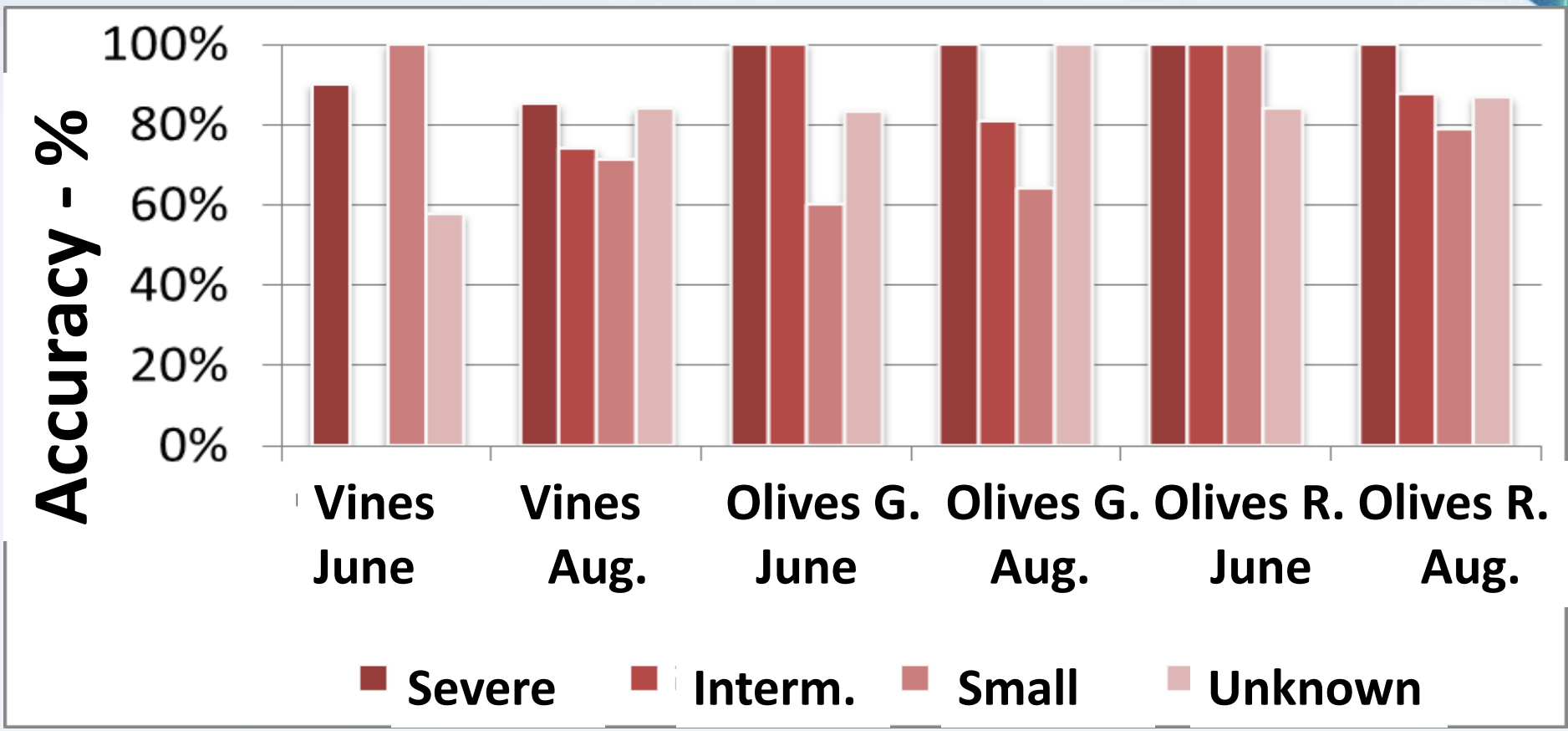


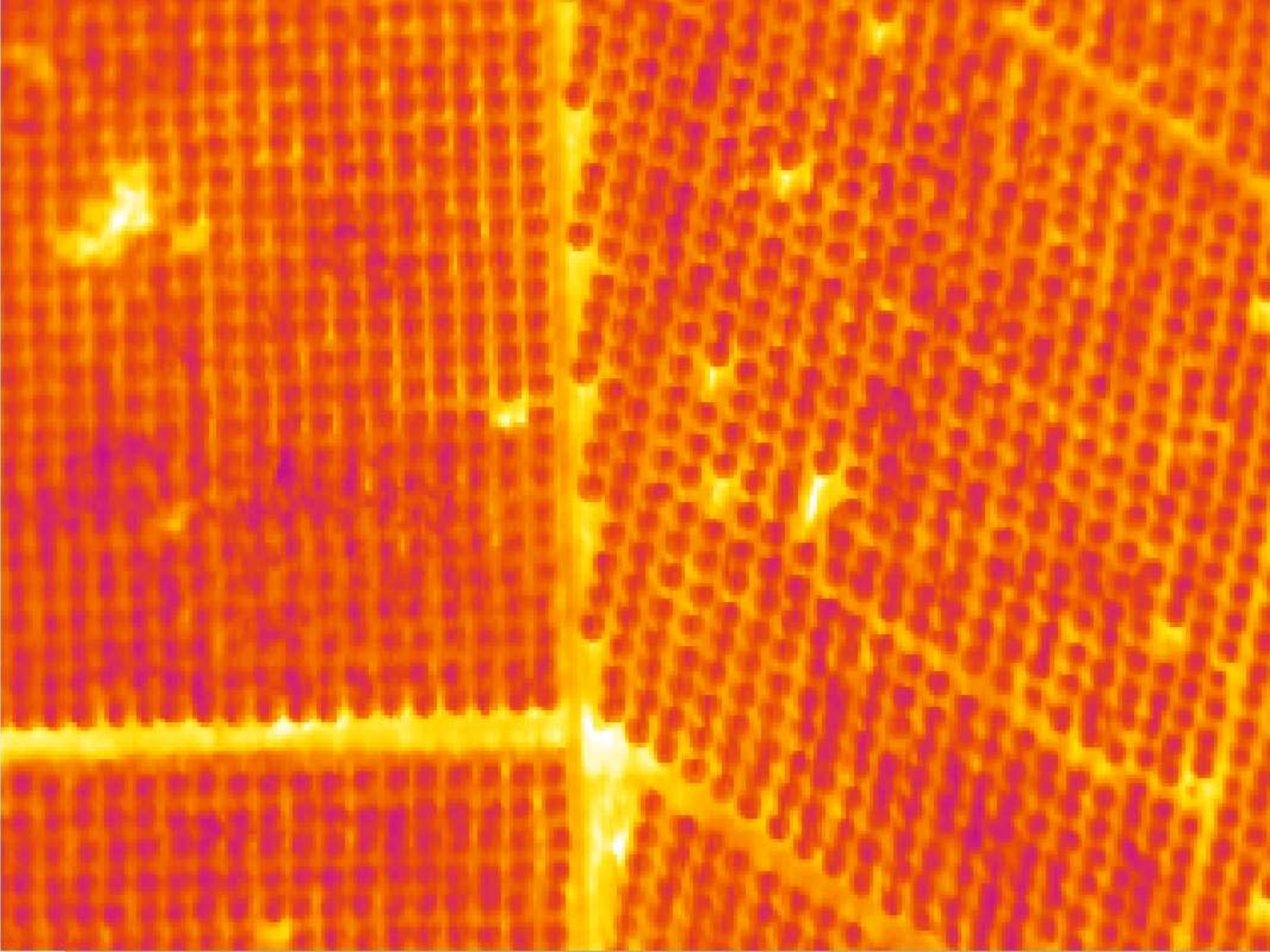
Index	x	y	Type
1	268135.5	741497.6	Low
2	268139.7	741535.4	Low
3	268141.5	741588.6	Low
4	268141.8	741593.8	Low
5	268146	741595.9	Low
6	268146	741560.9	Low
7	268147.1	741493	Low
8	268149.9	741595.6	Low
9	268151.3	741495.1	Low
10	268154.1	741595.2	Low
11	268154.1	741558.8	Low
12	268154.8	741529.8	Low
13	268157.9	741594.9	Low
14	268161.8	741594.5	Low
15	268162.8	741531.5	Low
16	268165.6	741594.2	Low

Automatic recognition



Detection accuracy of visible leaks

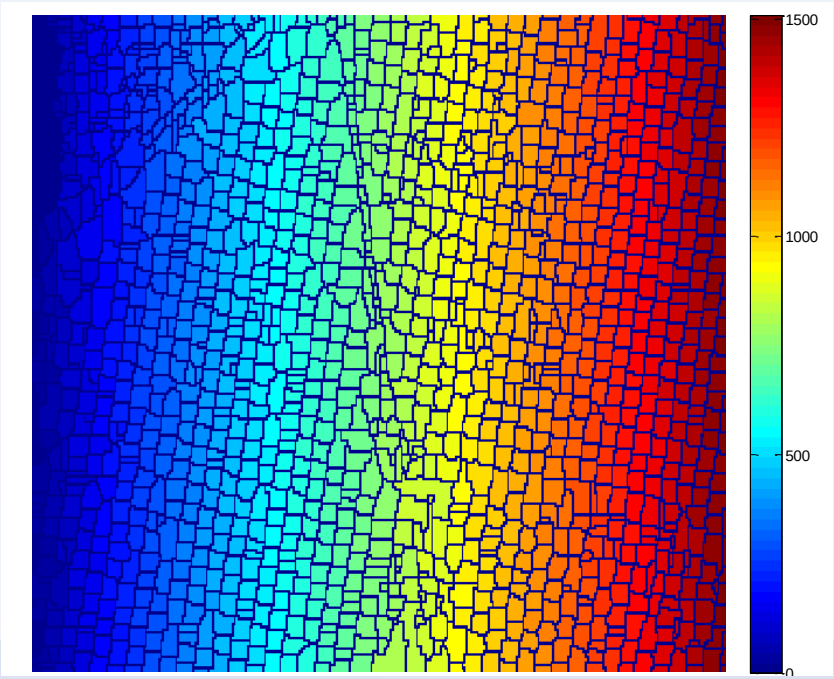




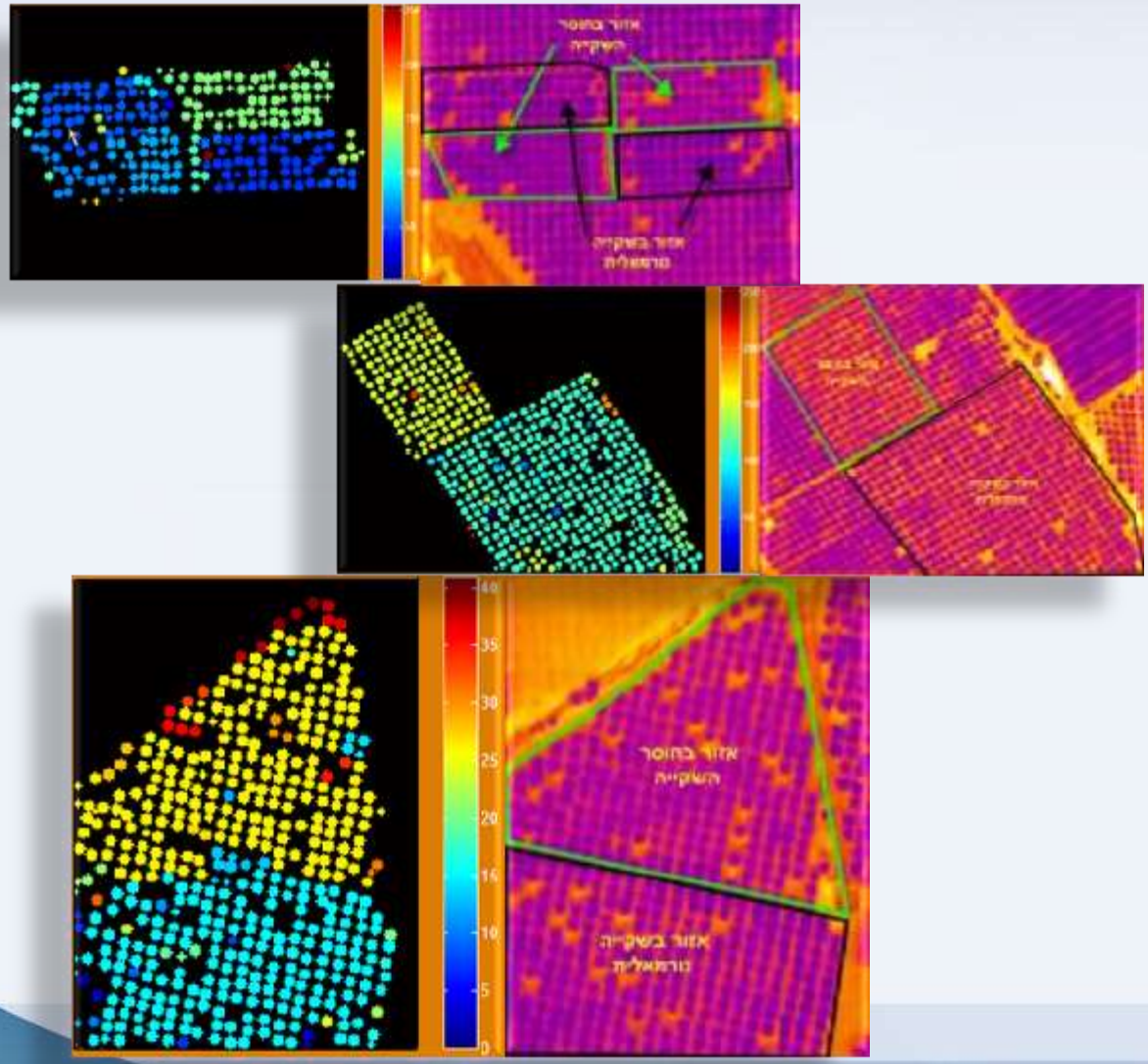
Analysis of Thermal Images

Canopy segmentation (Matlab)

- A watershed image processing algorithm was employed to the thermal image to outline the palms canopy.

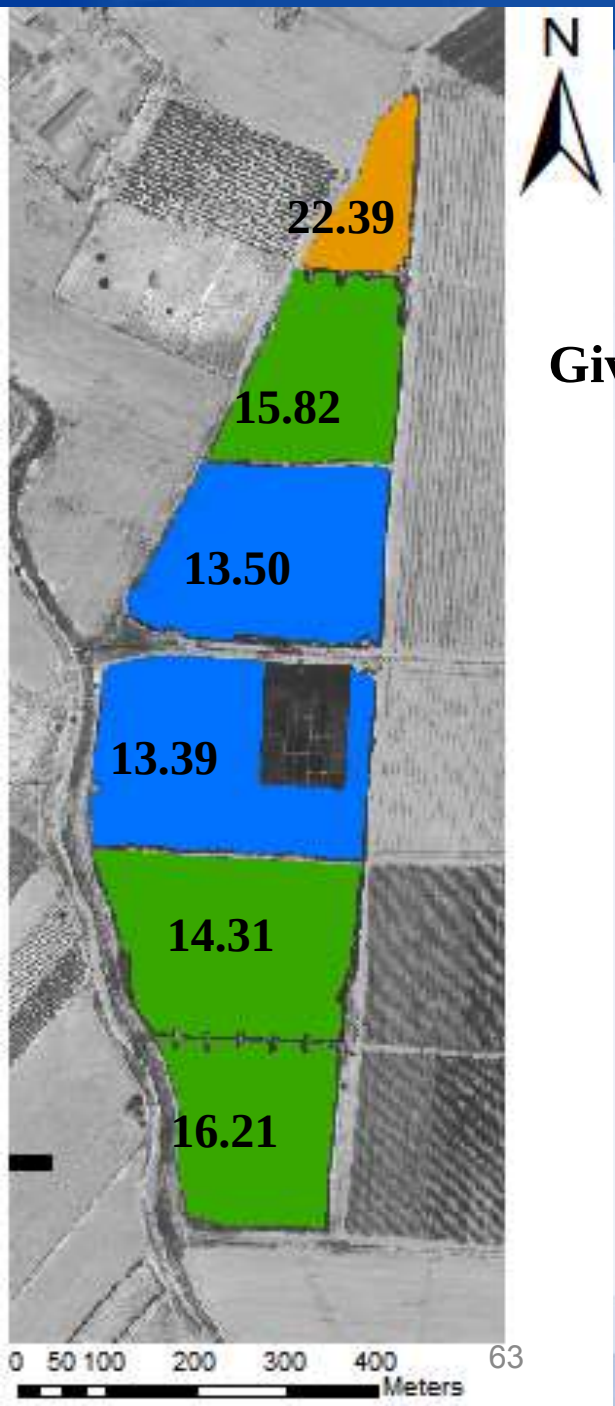


Results - Map of water status



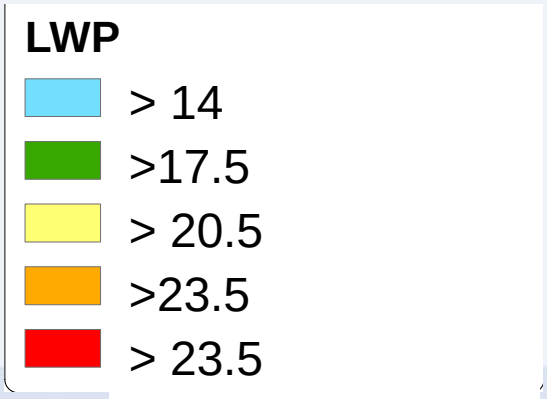
Maps of irrigation status based on temperature, for each site. The dashed borders delineate sub-plots irrigated with 100% of the recommended amount (sp-100%); the continuous borders delineate those under 20% deficit irrigation (sp-20%).

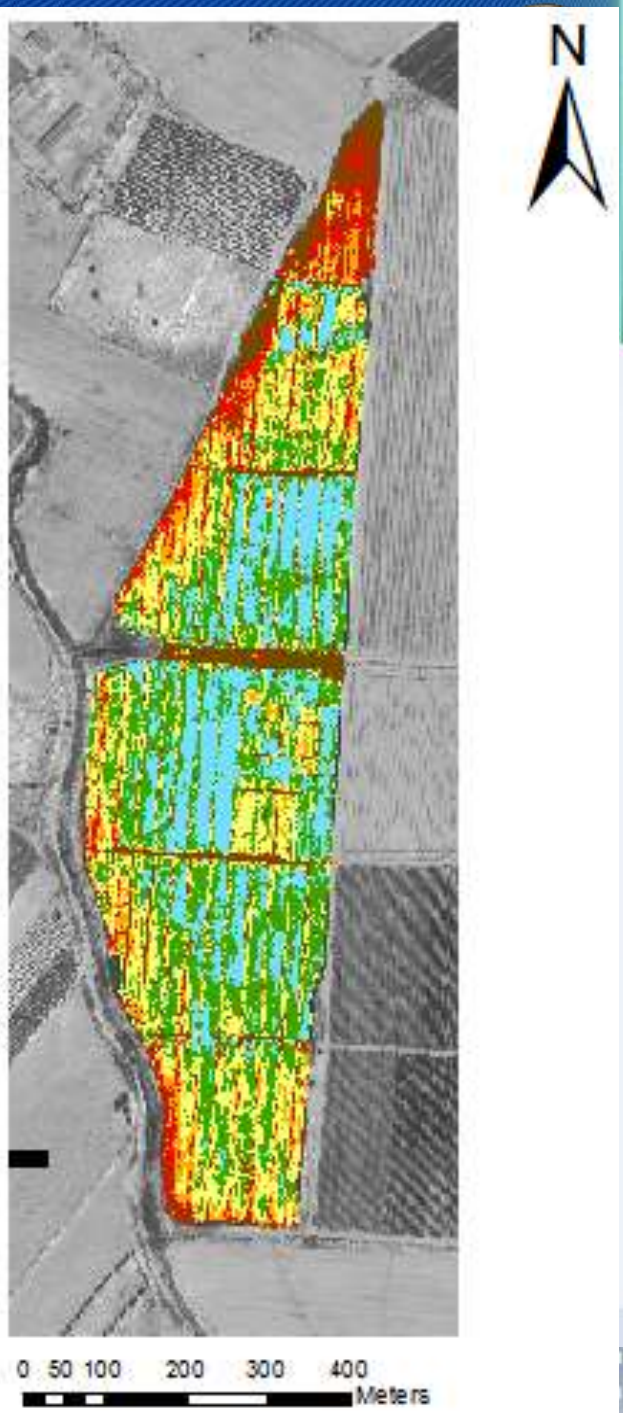
Cotton



LWP Map in Givat-Brener Field (11/08/13)

Algorithms for delineation of uniform management zones





- Weeds tend to grow in patches.
- Selective herbicide application.
  - Cost saving.
  - Environmental benefits.

Detection of weeds in high resolution images

- RGB images from UAV (Unmanned Aerial Vehicle) or ground vehicles (tractors)
- High resolution images.

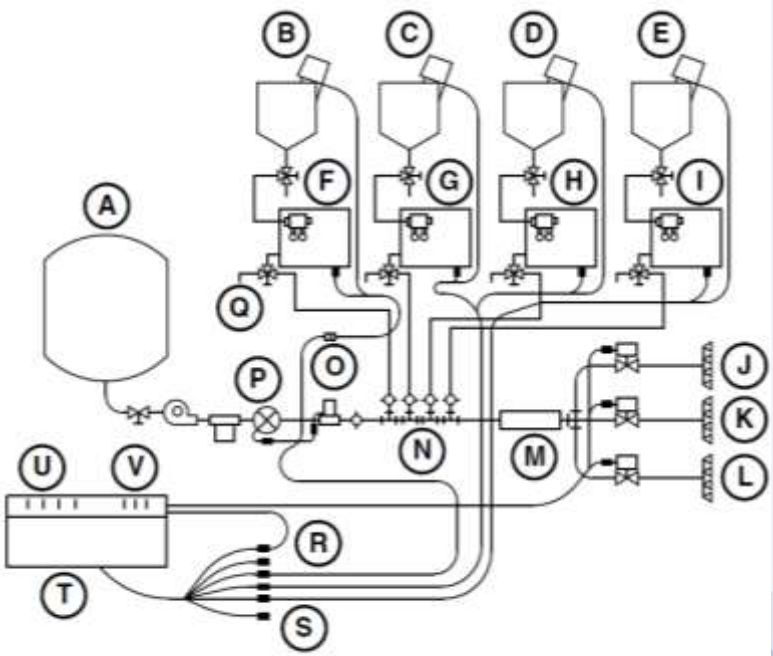


Fig. 27 — Chemical injection system

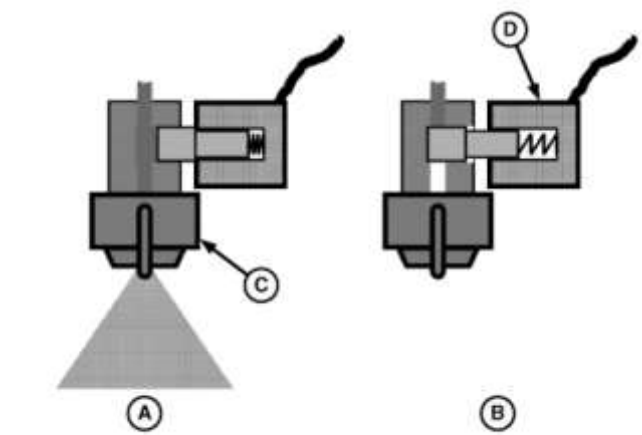
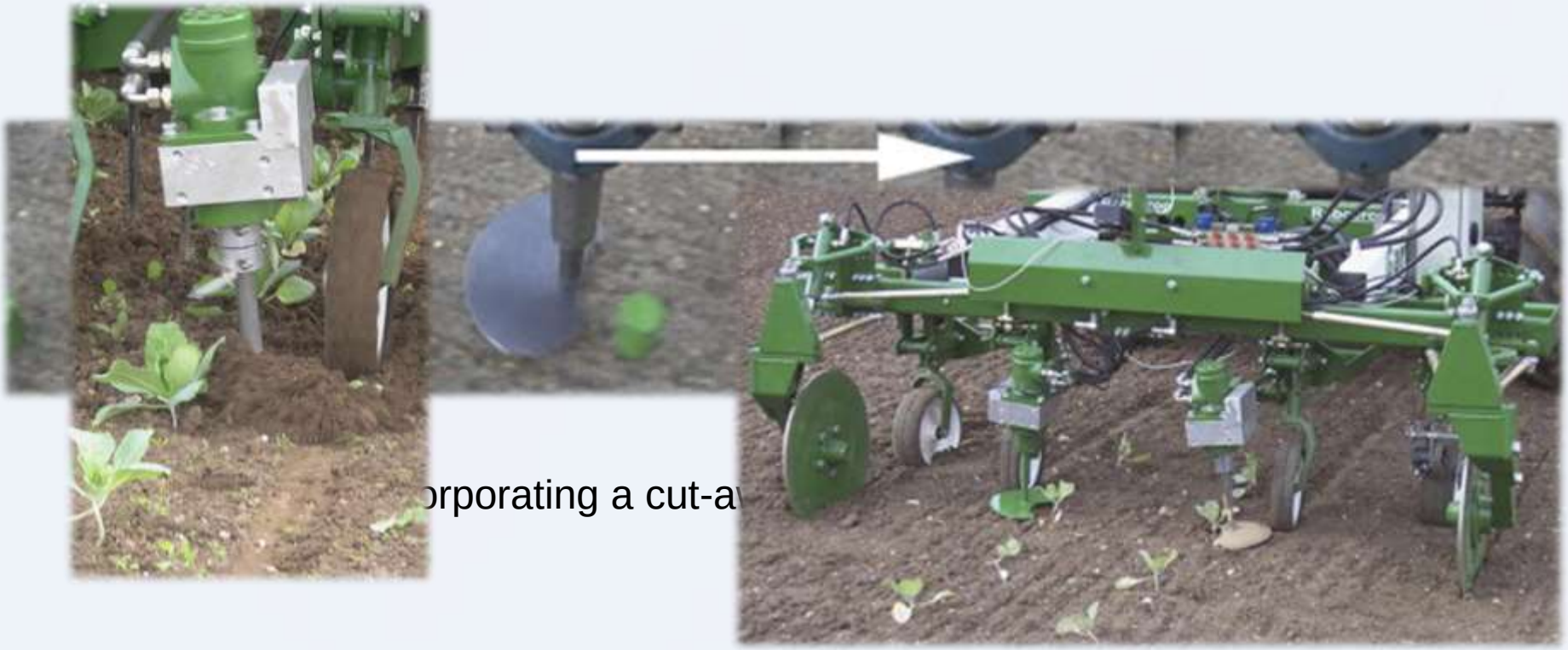


Fig. 26 — Illustration of a conventional nozzle equipped with a solenoid-actuated control valve

Mechanical within-row weed control for transplanted crops using computer vision



orporating a cut-a

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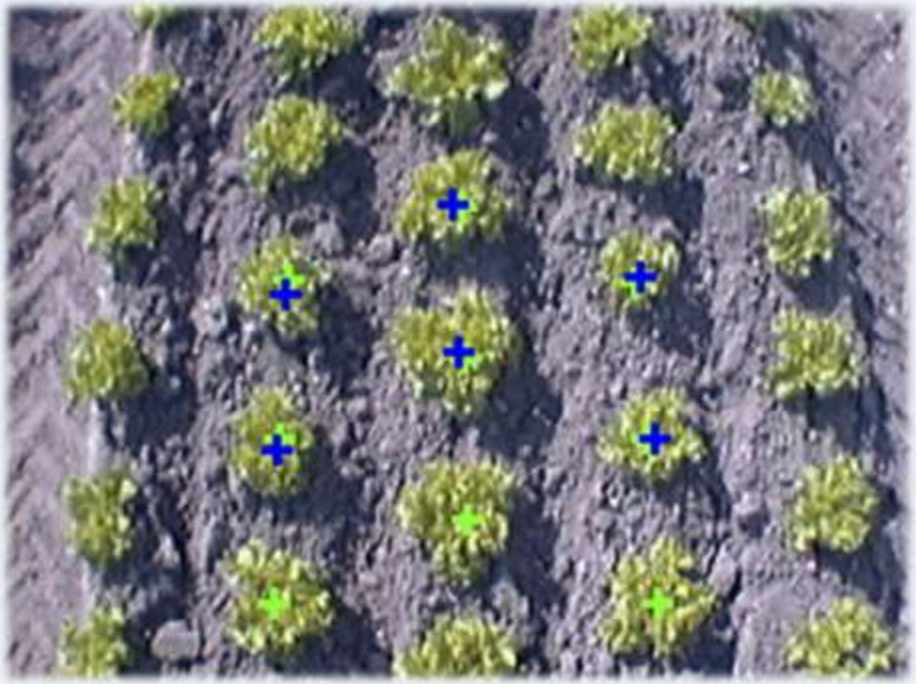
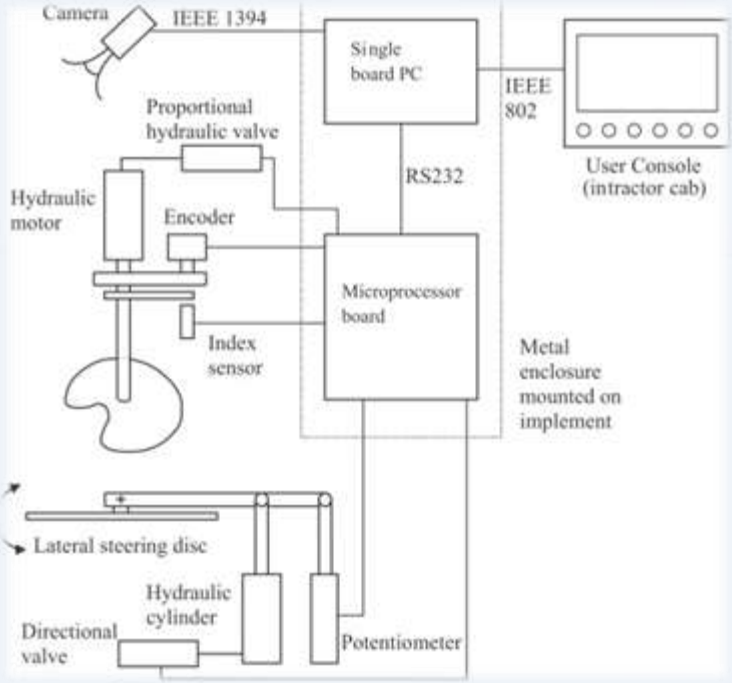
Mechanical within-row weed control for transplanted crops using computer vision





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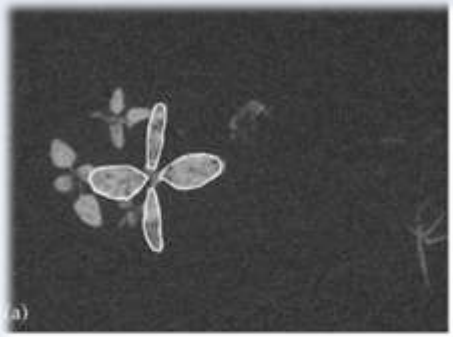
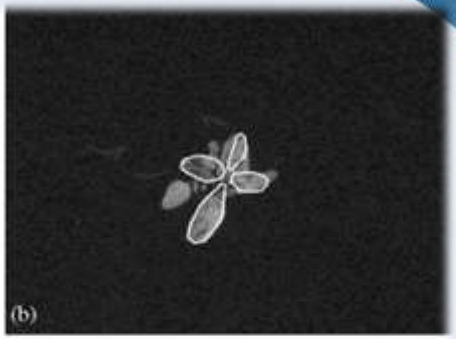
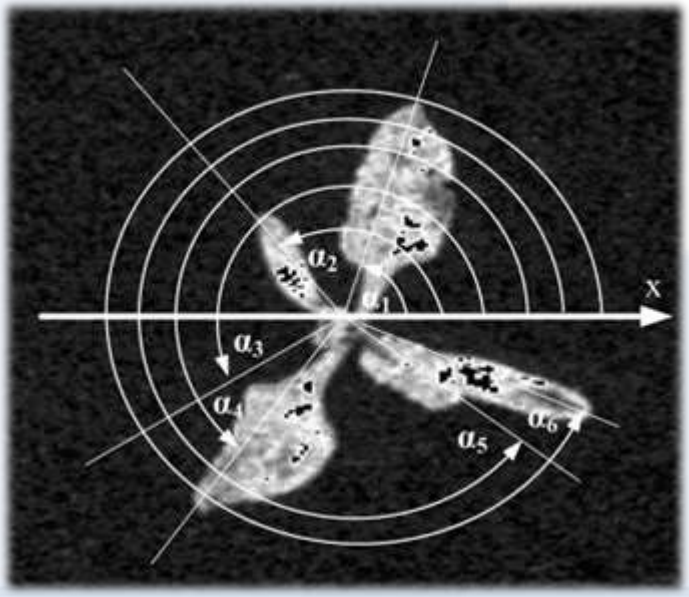
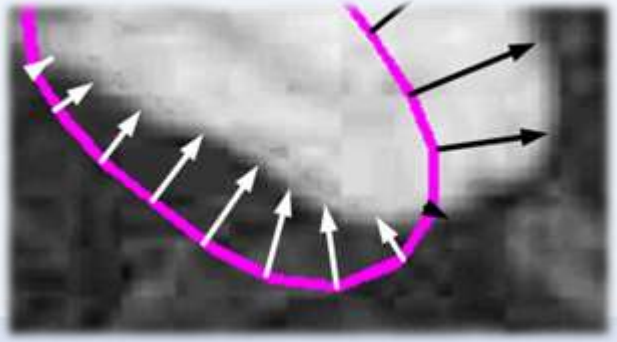
Classification of crops and weeds extracted by active shape models









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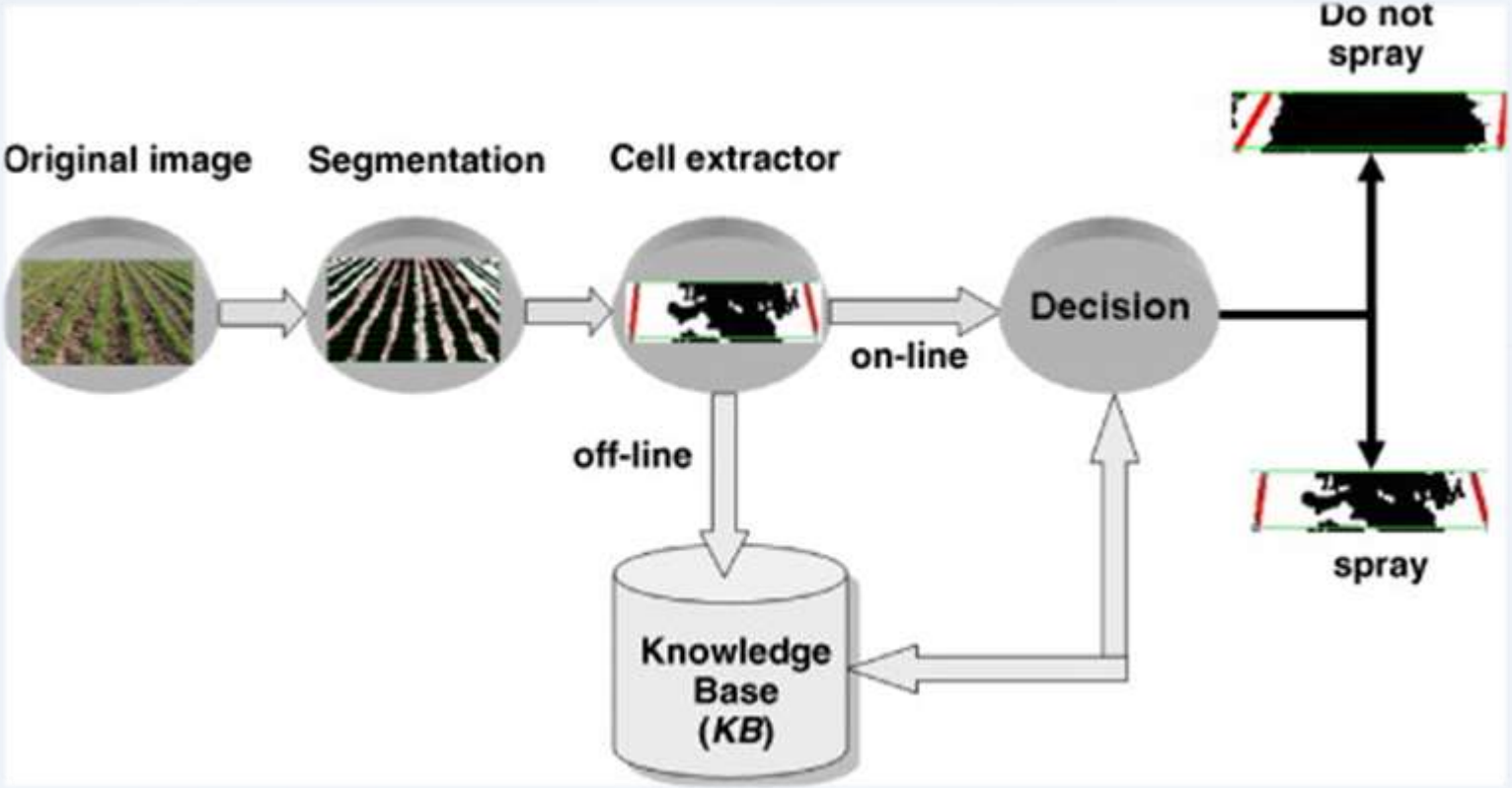
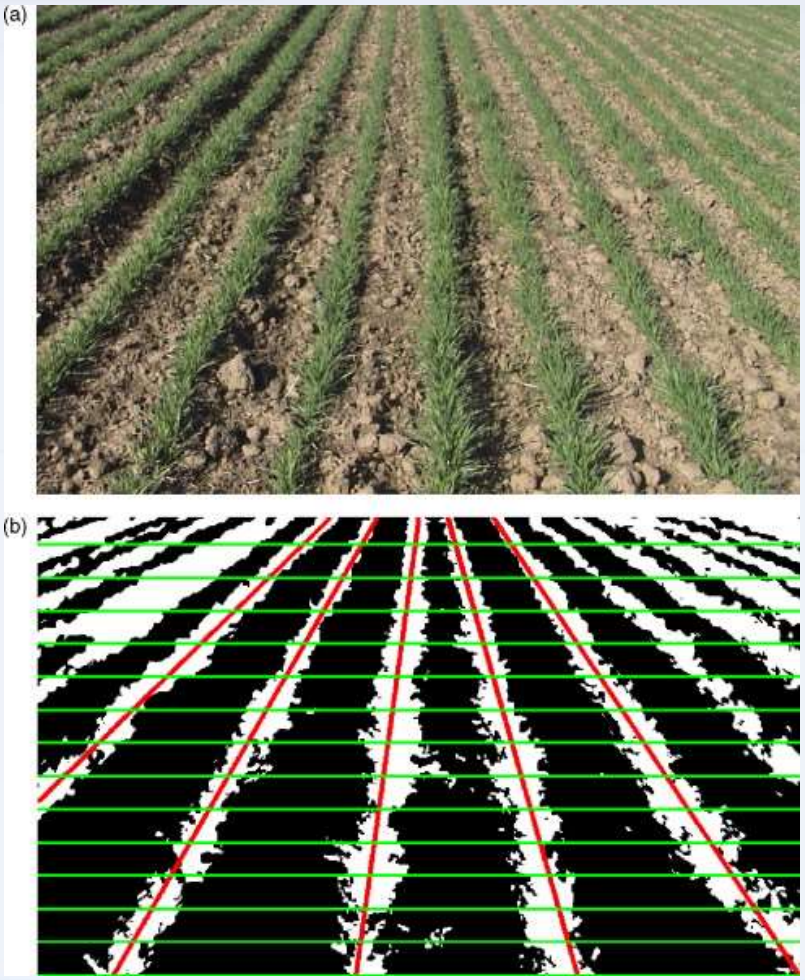
Vision-based approach to differential spraying in precision agriculture



Vision-based approach to differential spraying in precision agriculture



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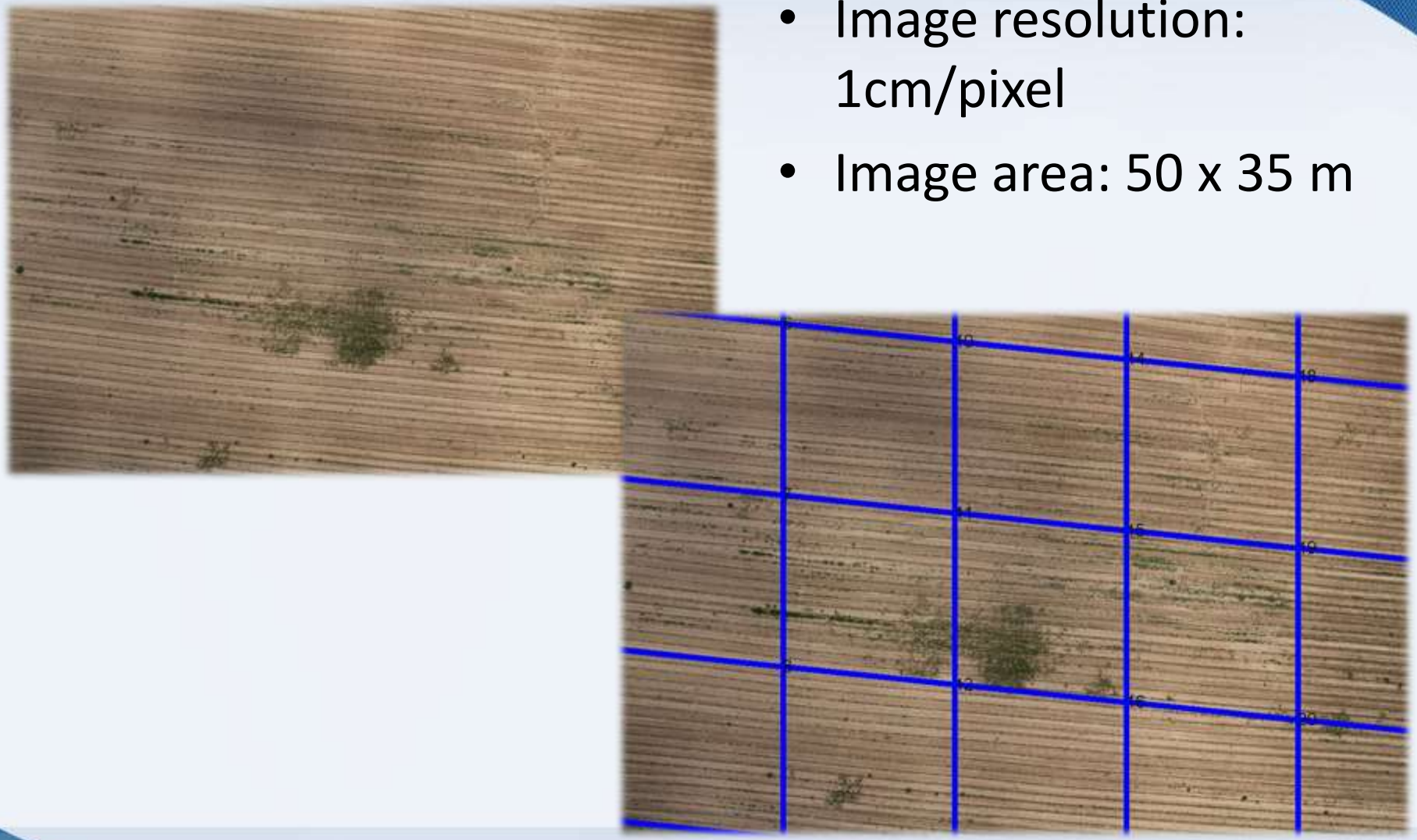
05/30/2012

Image acquisition

- Navigation of tetracopter
  - Autonomous navigation and acquisition
  - Height: 88m
- High resolution color camera:
  - Canon EOS Kiss X4, 5184 x 3456 pixels, exposure: 1/1000, f/7.1, ISO 200
- No mosaicking

Sample image



- Image resolution: 1cm/pixel
- Image area: 50 x 35 m

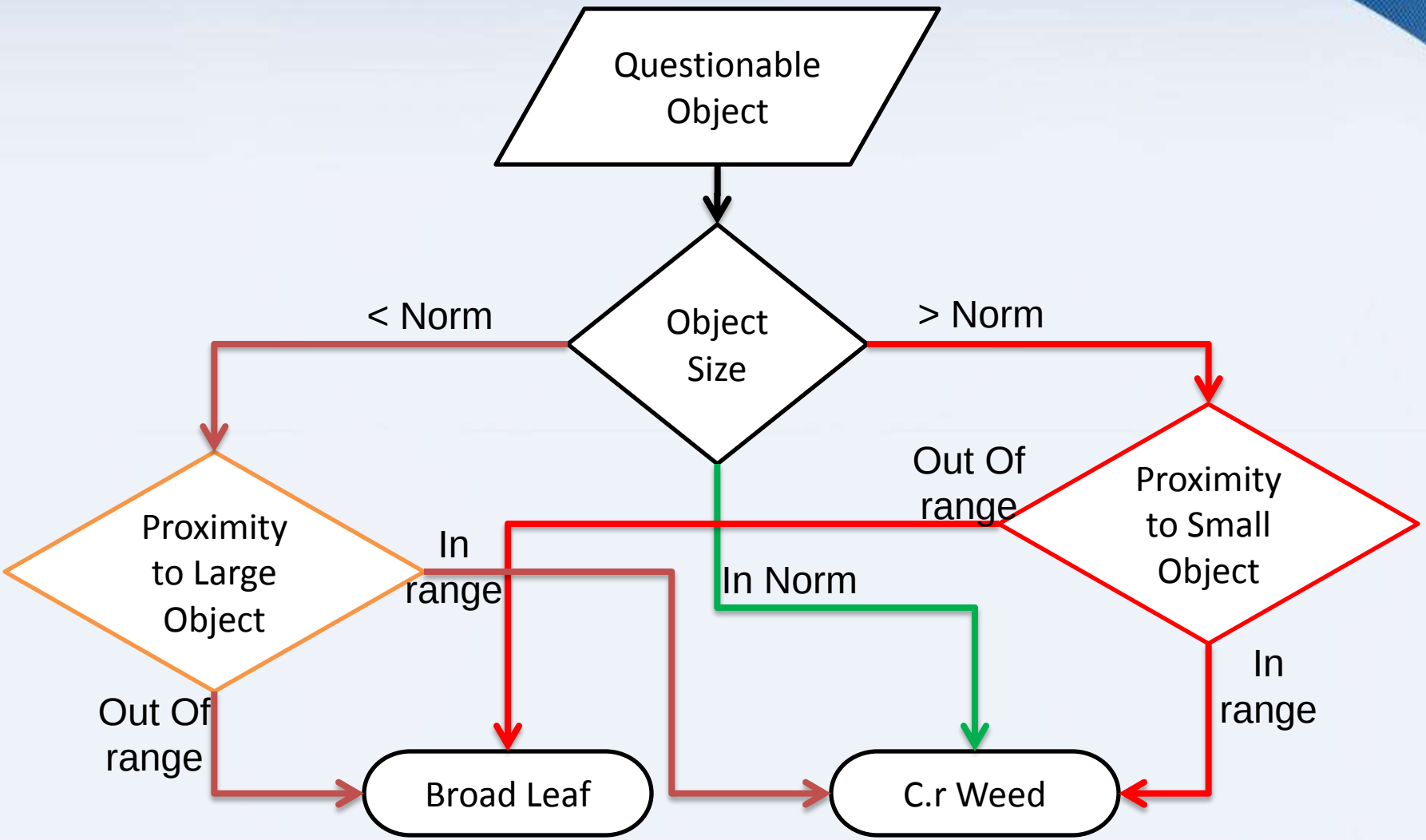
Levels of weed infestation

1- clean

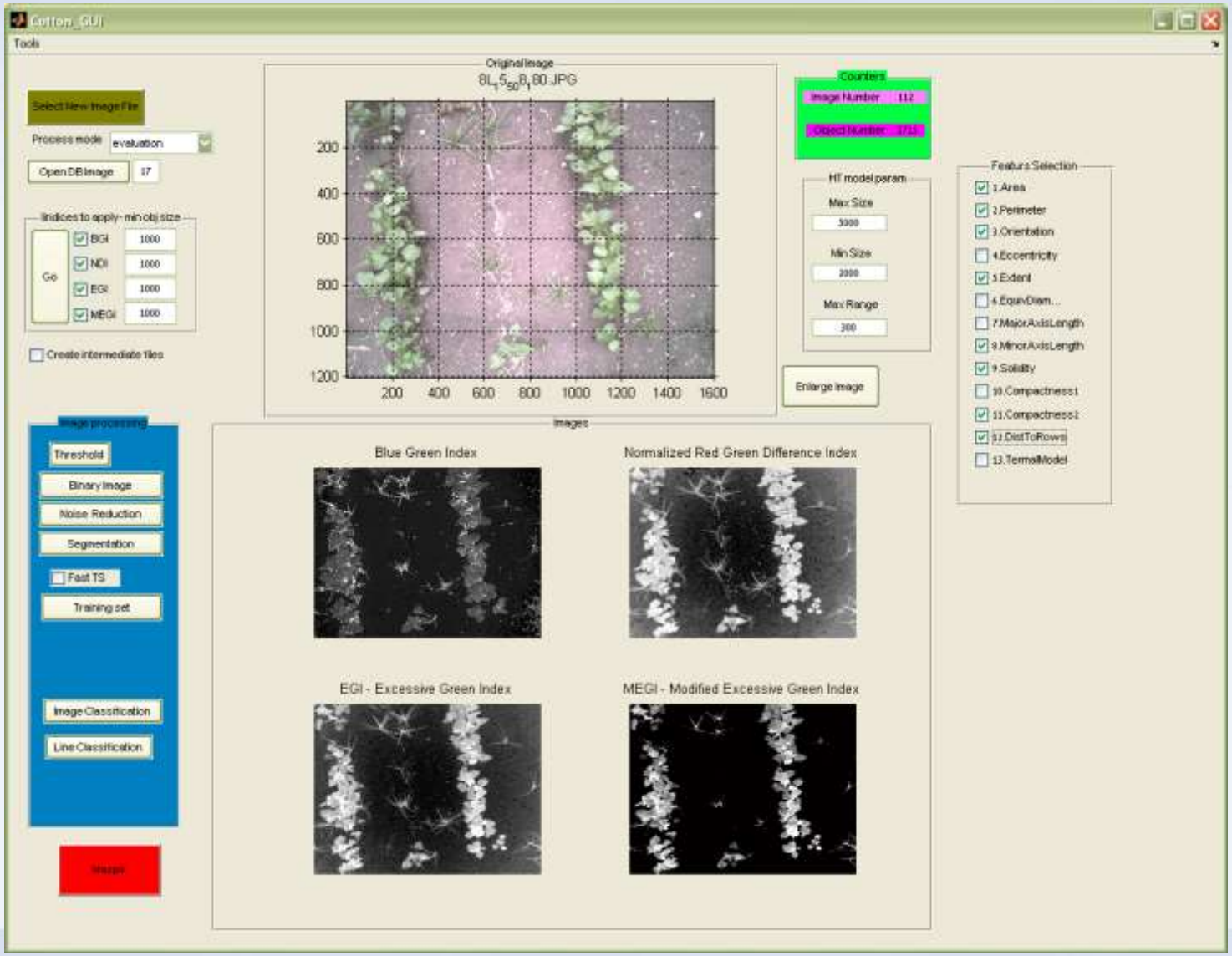
2 - medium

3 - high

Classification



Application Interface



Classified Image

C. rotundus-Single

C. rotundus-Cluster

Broadleaved Weeds

Cotton -Single

Cotton -Cluster

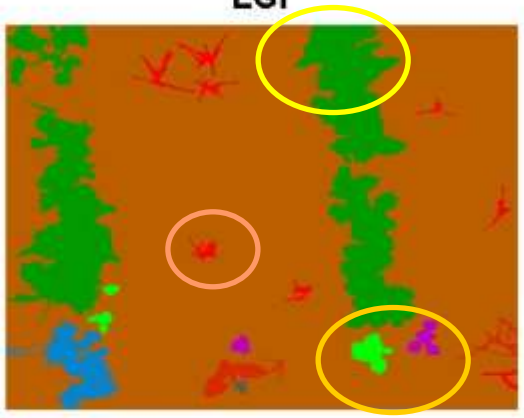
Mixture

Shade

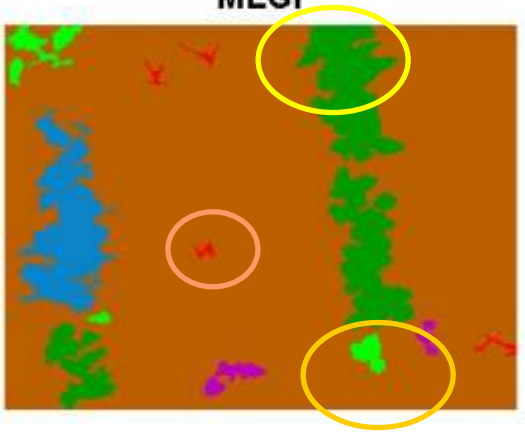
BGI

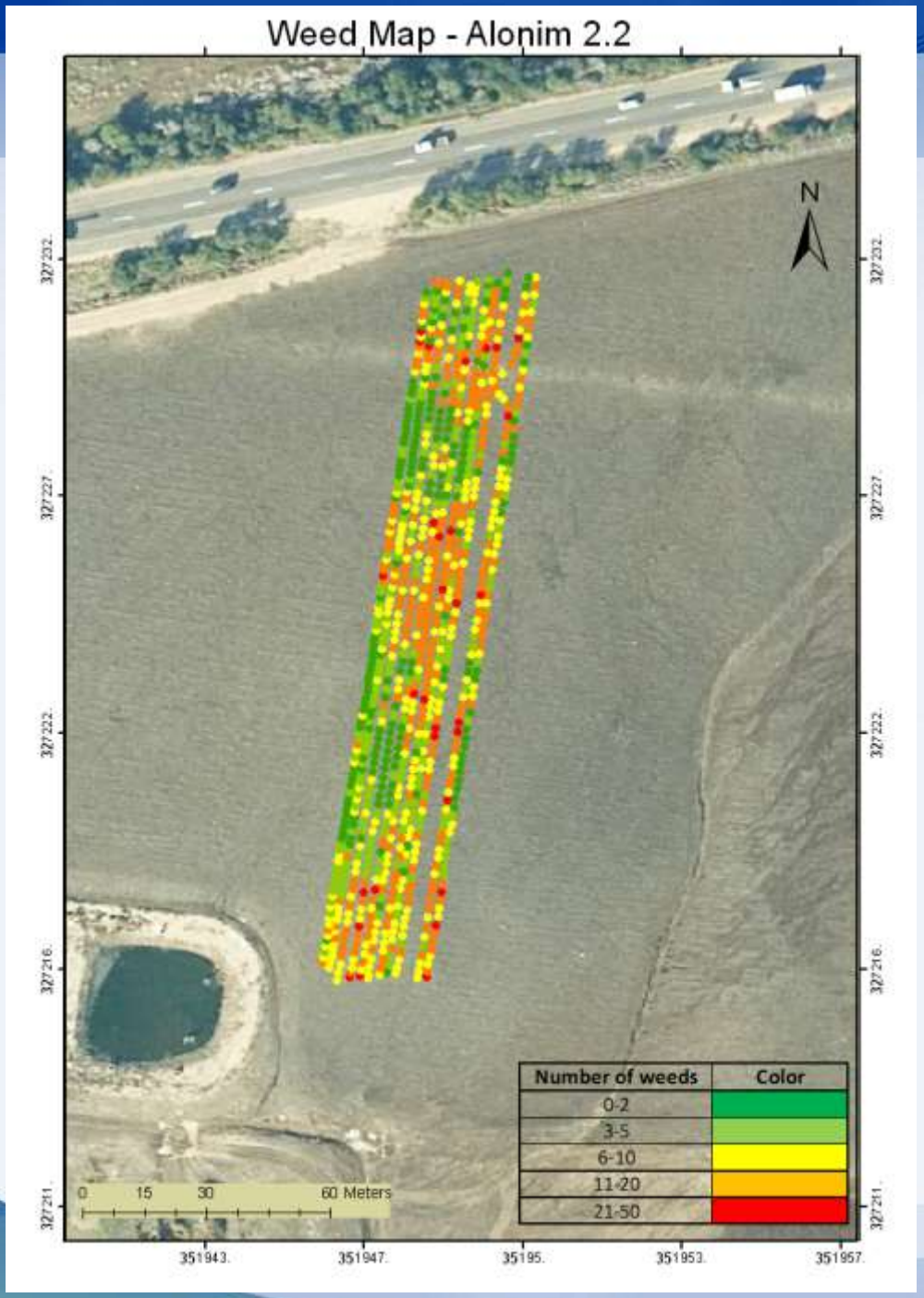
NDI

EGI



MEGI





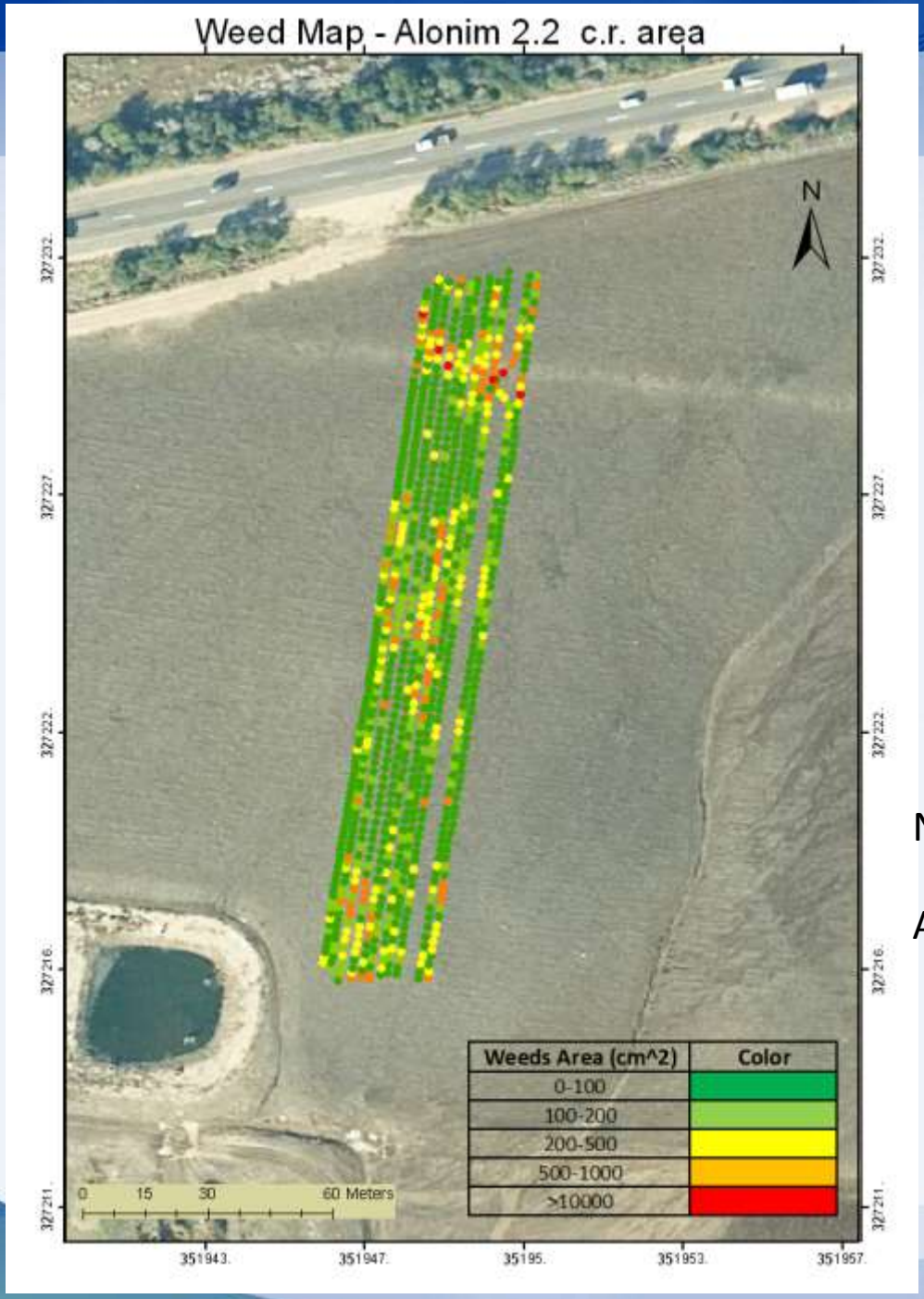
Weed Map

Number of narrow leaf weeds per Image.

Area of narrow leaf weeds per image.

Number of broad leaf weeds per Image.

Area of broad leaf weeds per image.



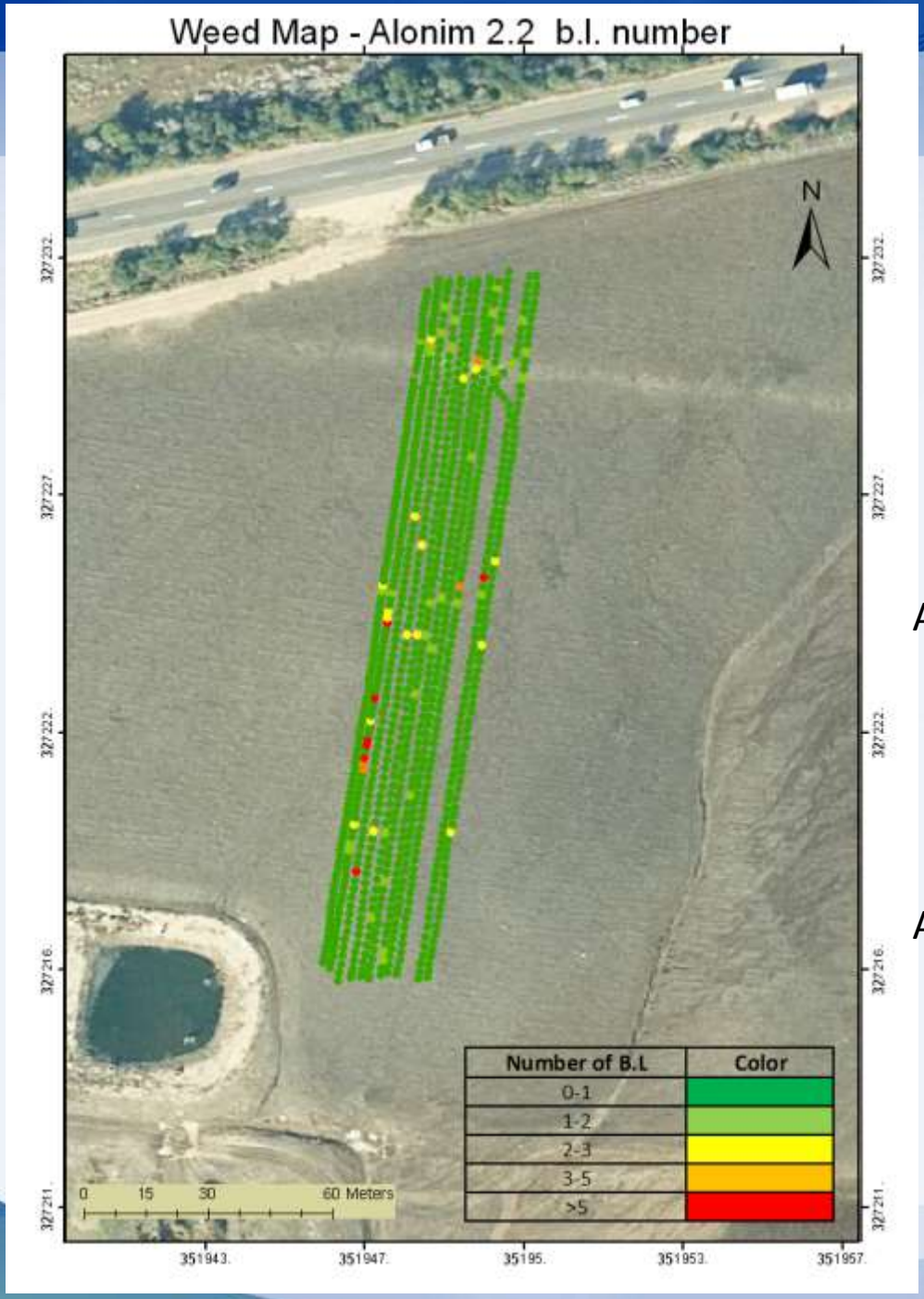
Weed Map

Number of narrow leaf weeds per Image.

Area of narrow leaf weeds per image.

Number of broad leaf weeds per Image.

Area of broad leaf weeds per image.



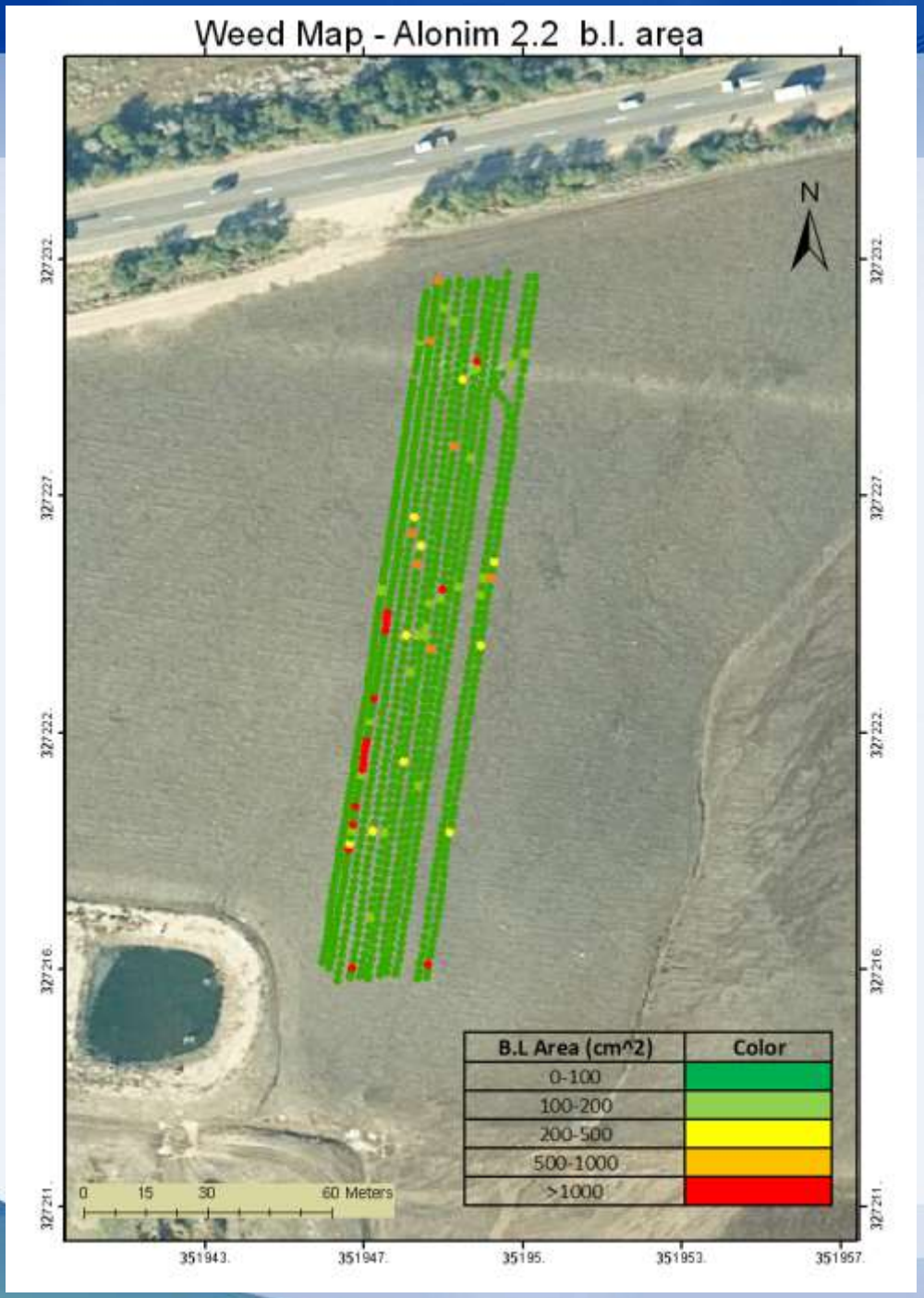
Weed Map

Number of narrow leaf weeds per Image.

Area of narrow leaf weeds per image.

Number of broad leaf weeds per Image.

Area of broad leaf weeds per image.



Weed Map

Number of narrow leaf weeds per Image.

Area of narrow leaf weeds per image.

Number of broad leaf weeds per Image.

Area of broad leaf weeds per image.

Summary

Machine vision gets increasing attention in agricultural applications

- Livestock and aquaculture
  - Precision Livestock Farming – PLF
- Produce sorting and grading
- Precision Agriculture – PA
  - High resolution images

Questions…

Thank you!