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The Characterization of Humidity Condensation and Associated Effects Using Image Processing Techniques

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Introduction

The Basic Functions of Life Support System

Revitalisation of Air

Food Production

Quality Control

Water Production

Security Questions

Waste Management

- Constraints:

  - quality & treatment of the air in a greenhouse or manned capsule

  - control of condensation phenomenon: health risks (nosocomial infections), mould, rot/corrosion, light transmission…

Concept of Study : Basics of condensation

Condensation

Filemwise | **Dropwise**

Heat Transfer Coefficient $h_{film} << h_{drop}$

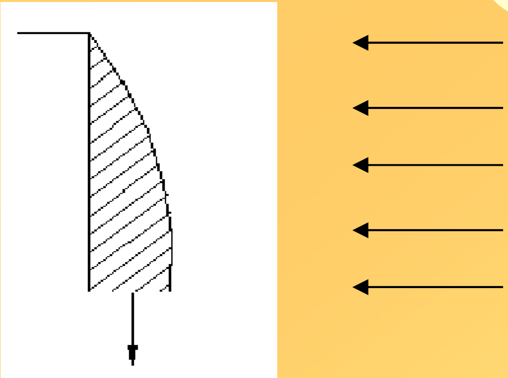
Filemwise

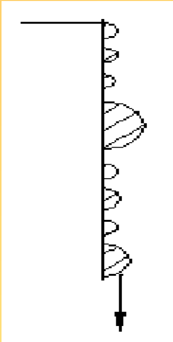
- Liquid wets the surface.
- Continuous film over the surface, that flows down the surface under the action of gravity.
- The layer of liquid condensate acts as a barrier to heat flow, and hence low heat transfer rate.

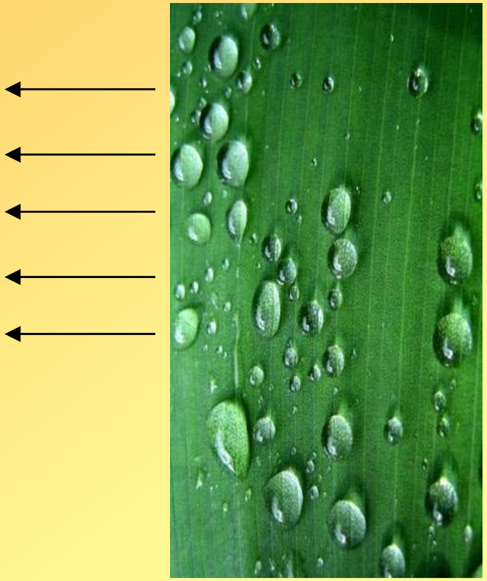
Dropwise

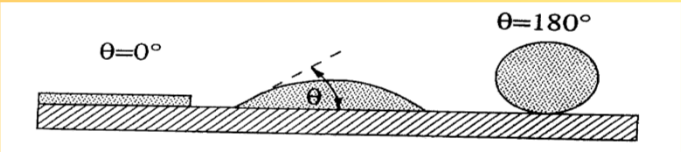
- Liquid does not wet the solid surface.
- Forms separate drops at nucleation sites.
- Drops coalesce to form large drops and sweeping clean a portion of the surface, where again new droplets are generated.

Notion

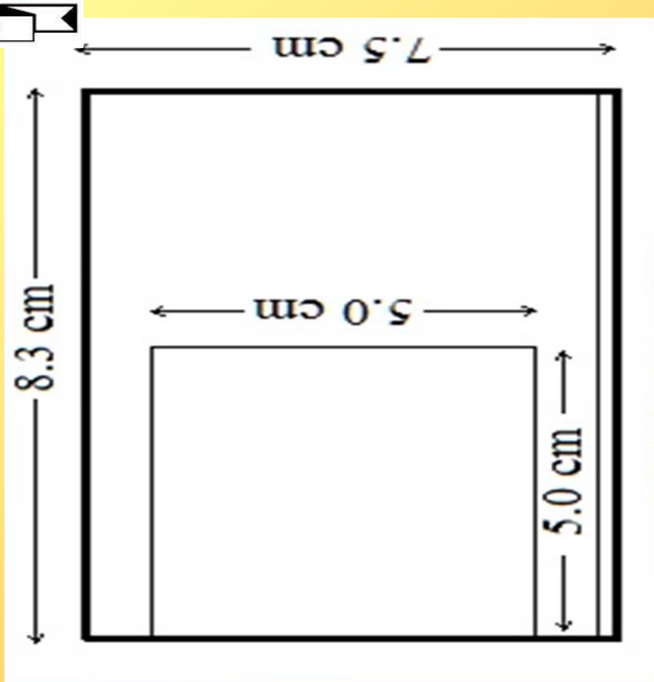




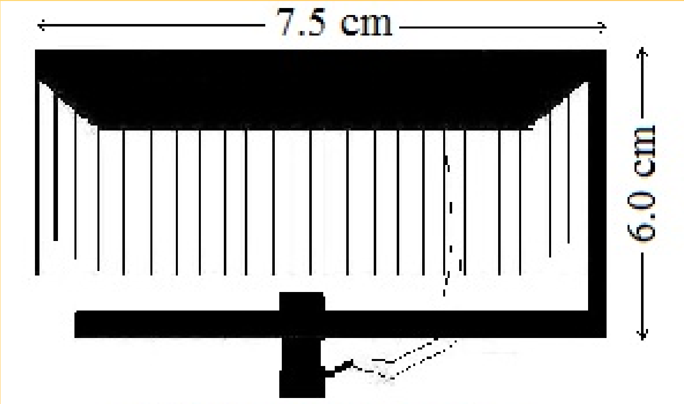




Dimensions of condensing unit



Dimension of upper side

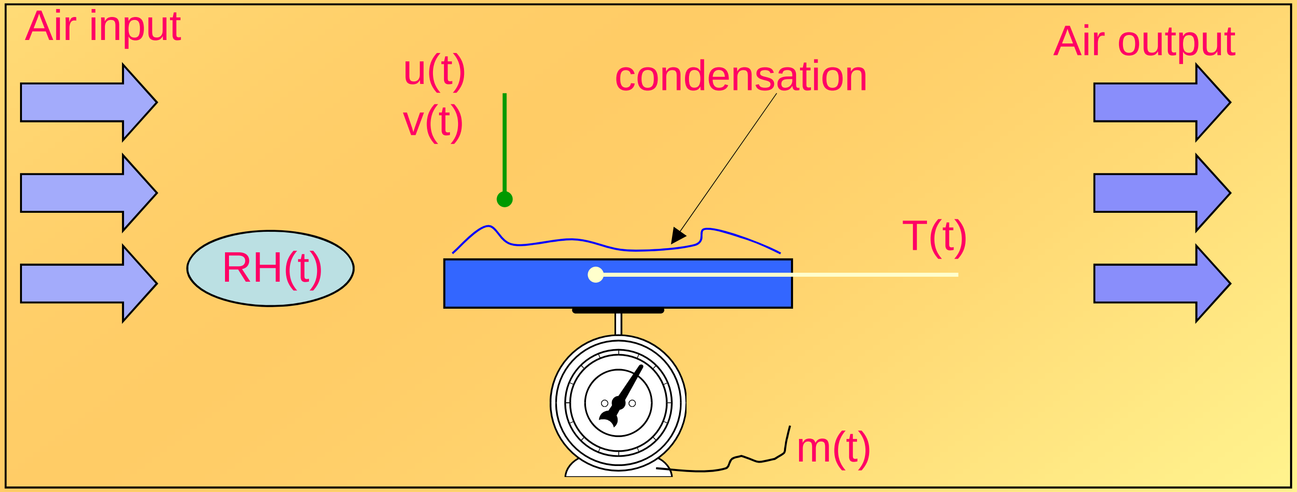


Finned front face side

Concept of the study

Mean entrance velocity (0.0 - 3.0 m/s), Temperature (19-23) ℃, Controlled RH 30-70%

Concept



Concept of study: Our approach

Dry phase

- experimental validation of concept
- measurements (velocity profile and temperature) in dry conditions
- comparison of these results for optimization and further modeling
- investigation of simple geometries (Horizontal plate)

Humid phase

- condensation of humid air (30-60%) in an open environment
- validation in a controlled wind tunnel (35-70%)
- mass transfer data has been discussed

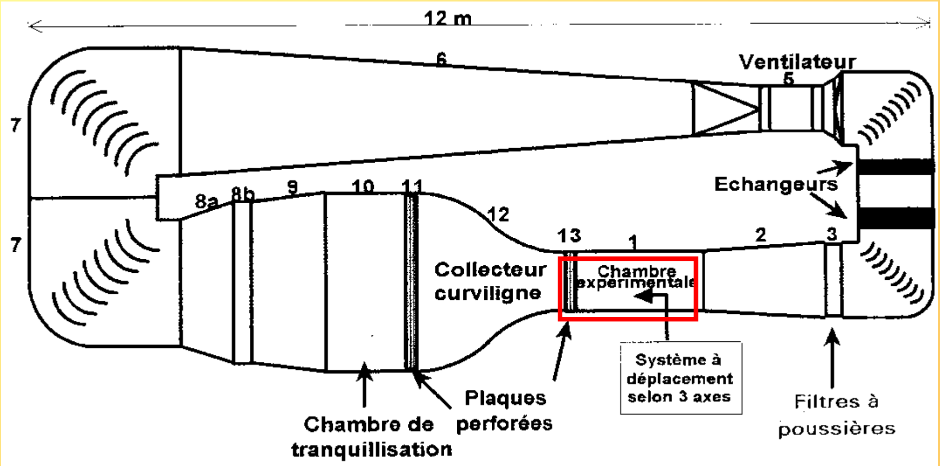
Experiments in open environment

Experimental arrangement

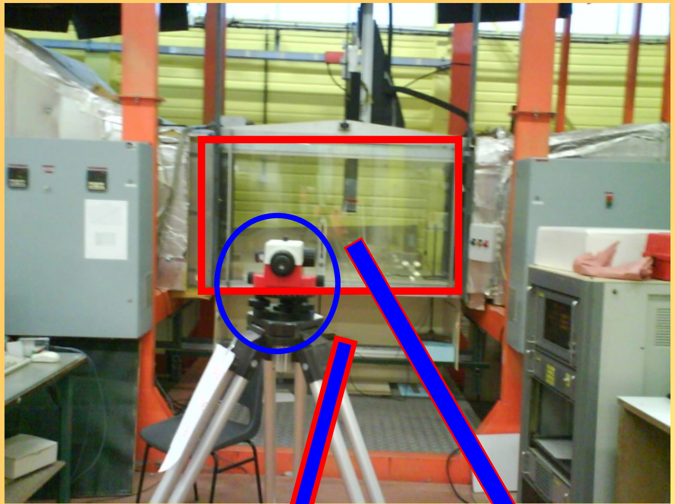
Active condensing plate

Wind Tunnel Facility

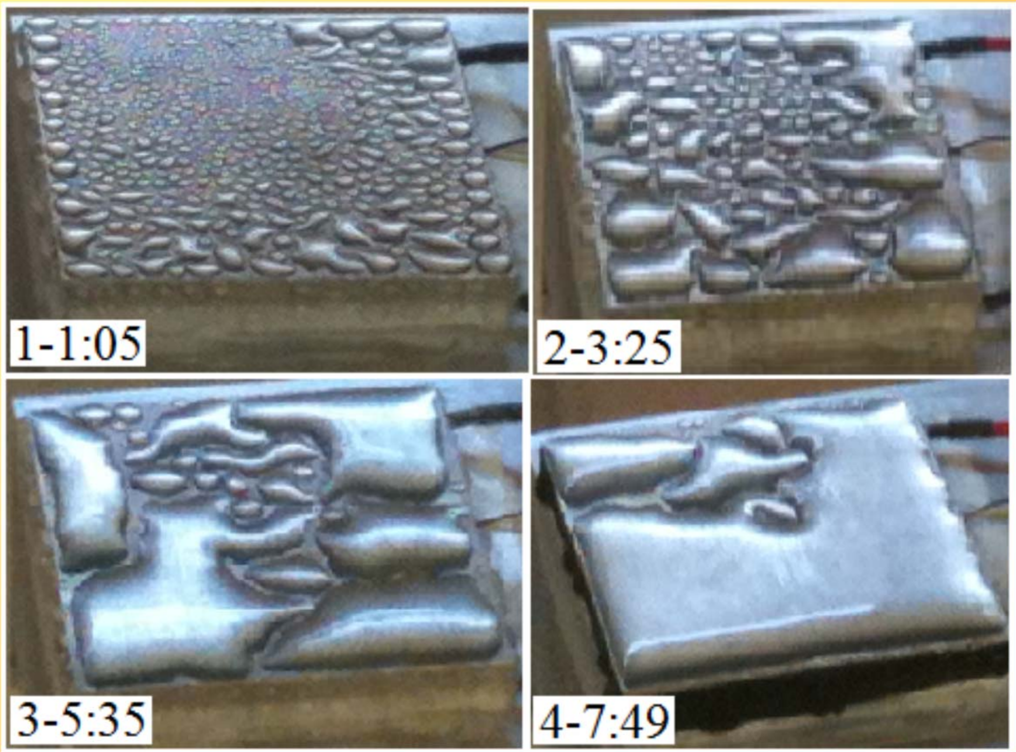
Schéma de la soufflerie en circuit fermé



Chambre de test

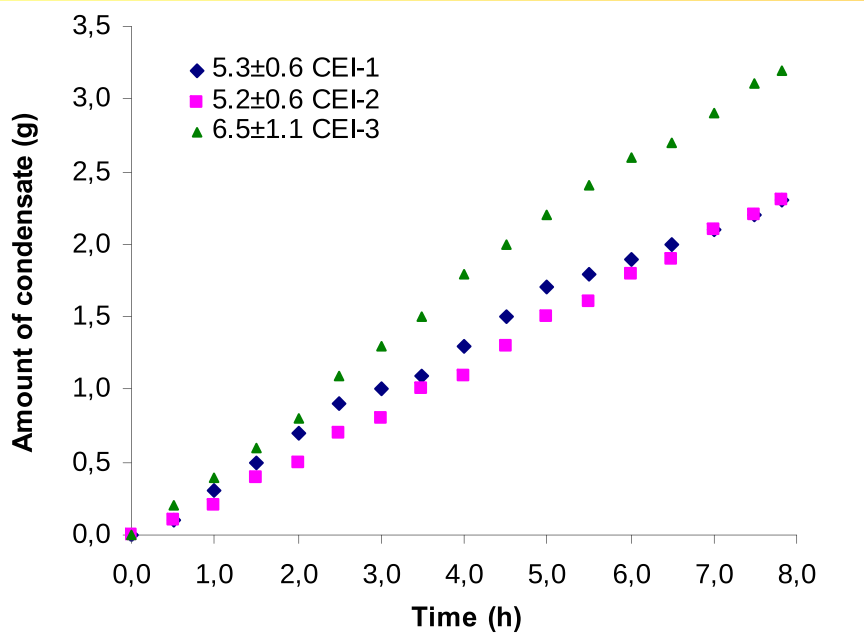


Growth of condensation drops

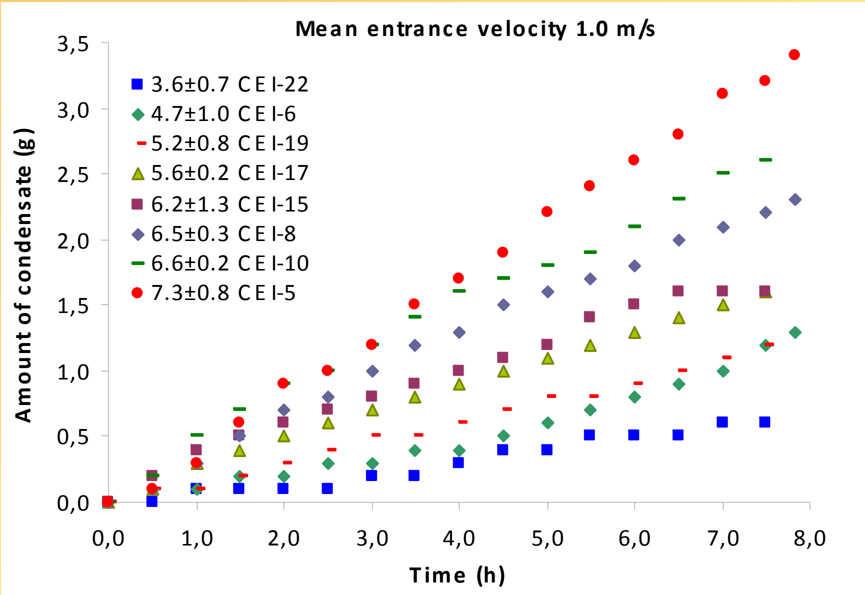


Photographs of the flat plate with condensation on it at different duration of time (in hours) after 1 hour of condensation.

Inside wind tunnel: Condensation mass flux



Amount of condensate versus time with different average temperature difference (ΔT_c) for 1.0 m.s^{-1}



Surface temperature estimation

1 $$T_s = \frac{T_c + T_a}{2} = T_c + 0.5(T_a - T_c)$$

2 $$T_{ref} = T_c + 0.31(T_a - T_c)$$ Minkowycz and Sparrow (1966)

3 $$T_s = \frac{3*T_c + T_a}{4} = T_c + 0.25(T_a - T_c)$$

4 $$T_s = \frac{5*T_c + T_a}{6} = T_c + 0.16(T_a - T_c)$$ **Our approach**

5 $$T_s = T_c + 1.0$$

6 $$T_s = T_d$$

Extreme cases

7 $T_f = (T_{sat} + T_s)/2$, Incropera and DeWitt (1990)
$T_s = (T_d + T_c) / 2$, *Where,* $T_{sat} = T_d$, $T_s = T_c$,

It gives approximately ±1.0 °C to our approach.

Mass flux calculations

For a flat plate in a parallel flow (laminar)

1 $$\overline{Sh_L} = 0.664\,\mathrm{Re}_L^{1/2}\,Sc^{1/3} \qquad 0.6 \le Sc \le 50$$

For turbulent flow, the local Sherwood number

$$Sh_L = 0.0296\,\mathrm{Re}_L^{4/5}\,Sc^{1/3} \qquad 0.6 \le Sc \le 300$$

And if it is a mixed type of flow, with a mixed boundary layer laminar/ turbulent,
the leading edge has a laminar boundary and approaching the rear edge it is turbulent, then

2 $$\overline{Sh_L} = 0.037\,\mathrm{Re}_L^{4/5}\,Sc^{1/3}$$

Where

$$\mathrm{Re} = \rho_\infty UL / \mu_\infty$$

$$Sc = \mu_\infty / \rho_s D$$

Mass flux (Asano, 2006)

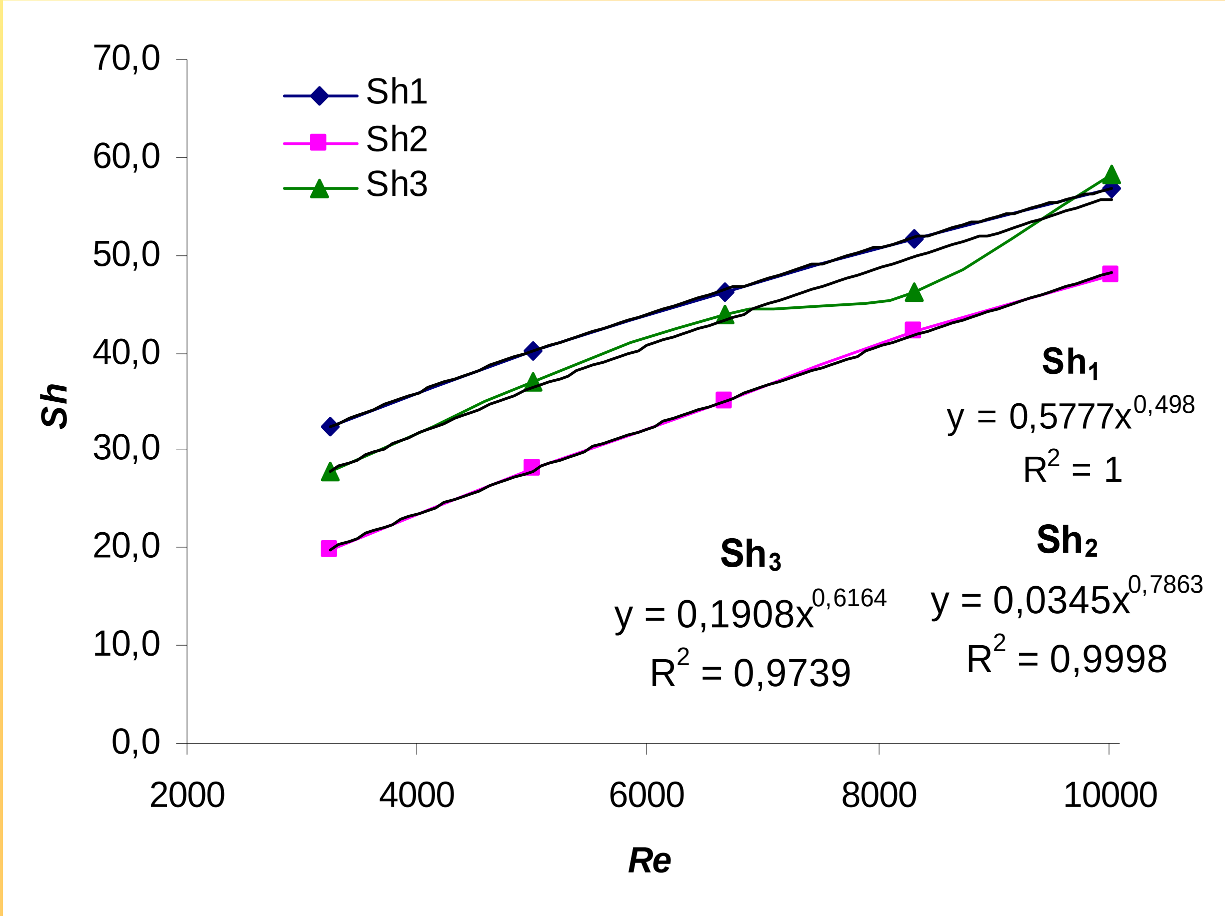
3 $$N = \frac{Sh\rho_s D(\omega_\infty - \omega_s)}{L}$$

Conclusions

$Sh_1 = X_1 . Re^{0.498}$

$Sh_2 = X_2 . Re^{0.786}$

$Sh_3 = X_3 . Re^{0.616}$



The relation We have proposed for this configuration:

$$Sh = 0.225\,\mathrm{Re}^{2/3}\,Sc^{1/3}$$

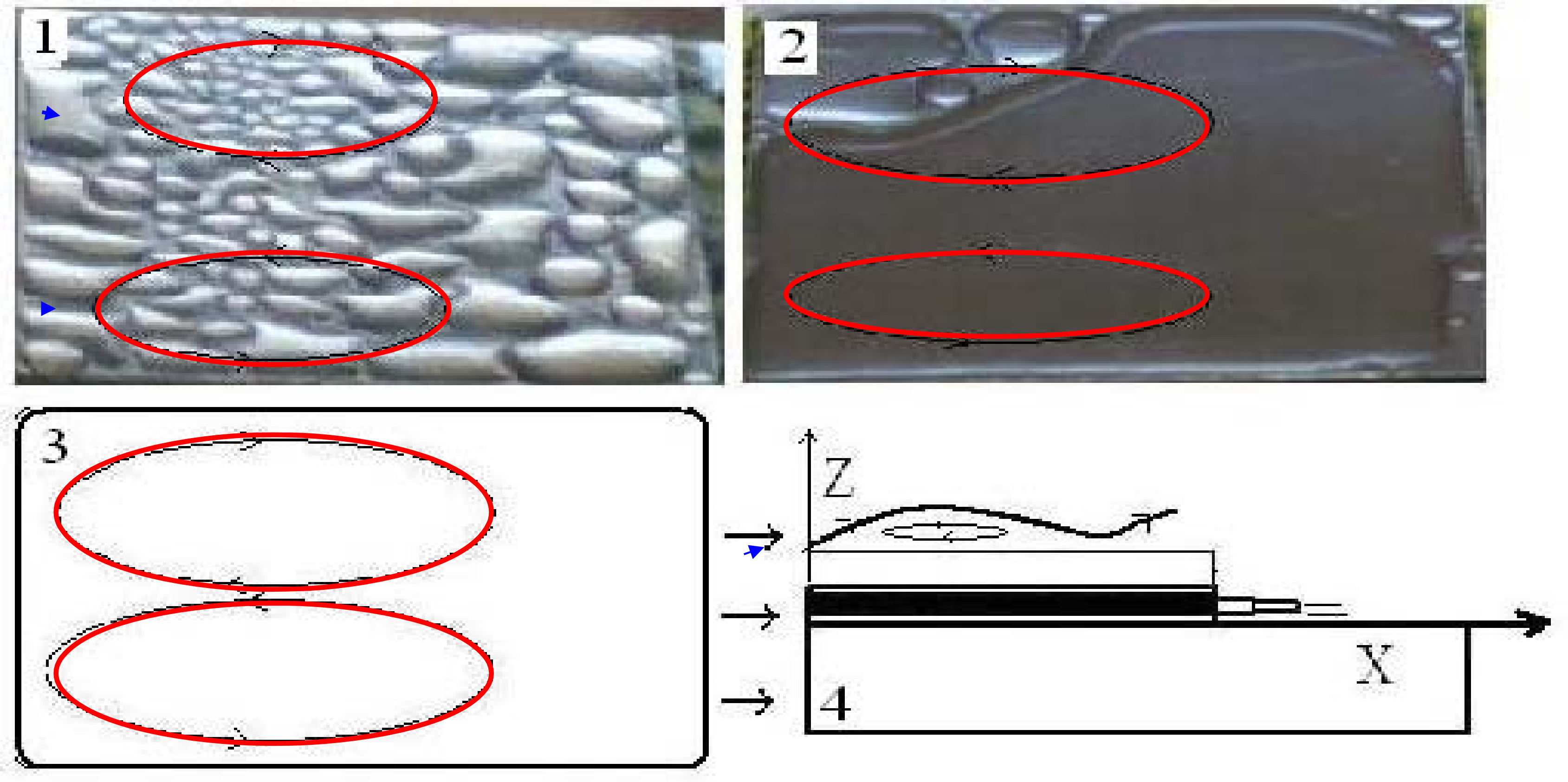
Where 3000 < *Re* < 10000

***Sc* = 0.6**

Visualisation of Condensation pattern

Flow Patterns

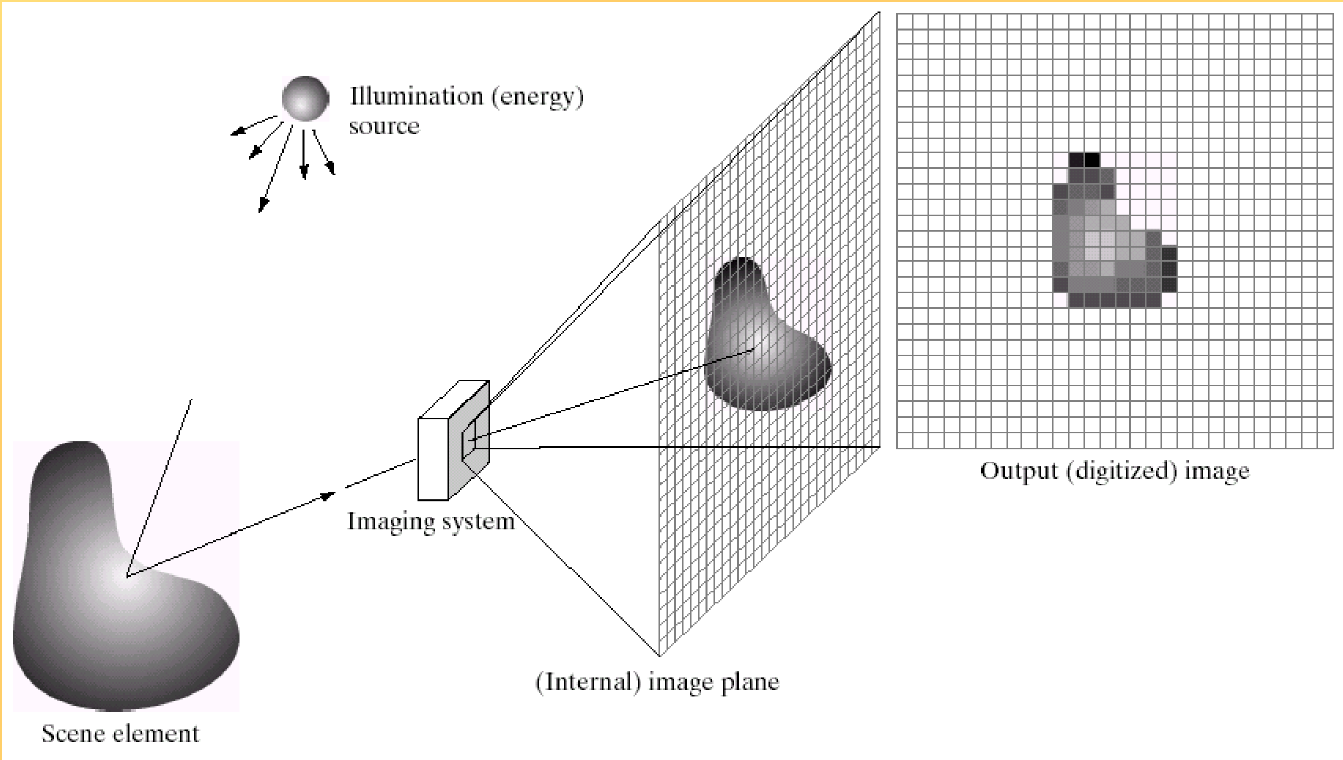
At the entrance of the wind tunnel the flow was weakly turbulent



- Indication of 2 counter-rotating vortices that extend from the leading edge to near the reattachment zone.
- The drops are like pulled out by those 2 counter-rotating vortices and pushed towards the rear part (2/3 to 3/4 of the length).

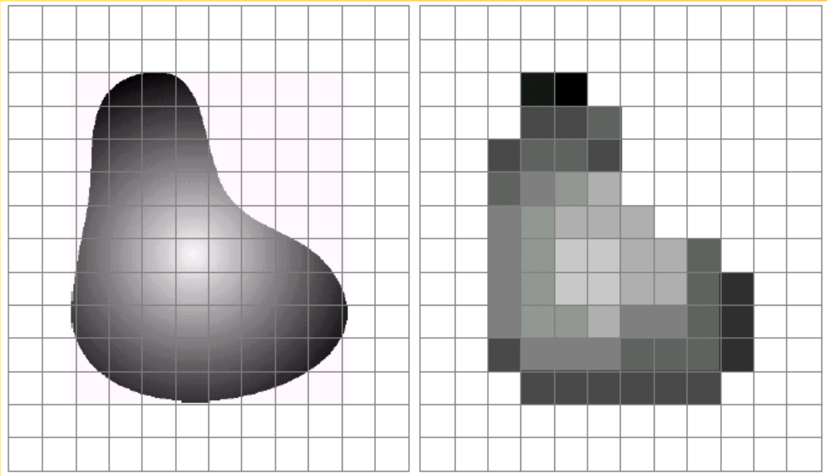
Digital Image?

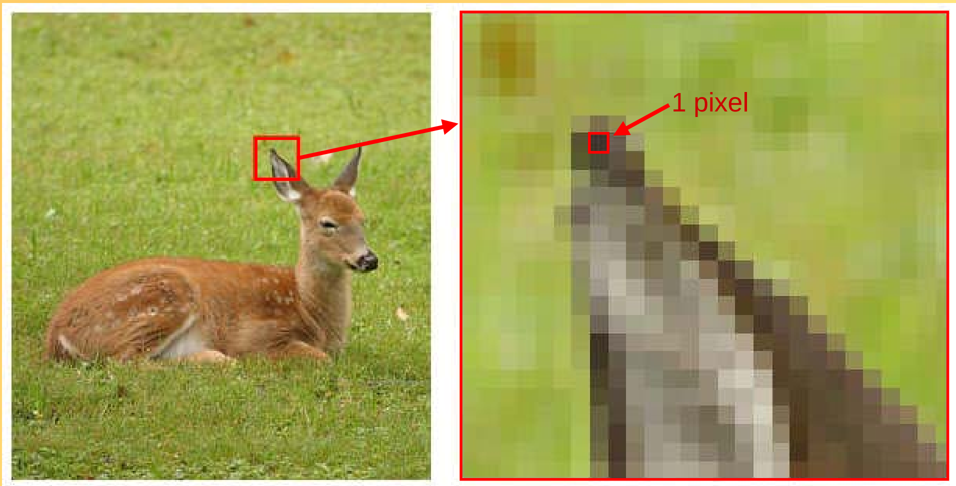
•A **digital image** is a representation of a two-dimensional (2-D) image as a finite set of digital values, called picture elements or pixels



WHAT IS PIXEL VALUES AND DIGITALIZATION?

- Pixel values typically represent gray levels, colors, heights, opacities etc
- *Digitization* implies that a digital image is an *approximation* of a real scene





WHAT ARE IMAGE FORMATS?

- Common image formats include:
  - 1 sample per point (B&W or Grayscale)
  - 3 samples per point (Red, Green, and Blue)
  - 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)

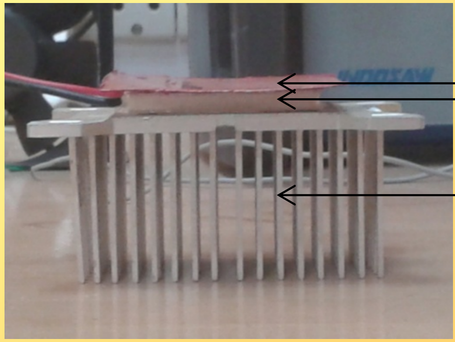
WHAT IS DIGITAL IMAGE PROCESSING?

- The continuation from image processing to computer or Artificial vision can be broken up into low-, mid- and high-level processes

Low Level Process	Mid Level Process	High Level Process
Input: Image **Output:** Image	**Input:** Image **Output:** Attributes	**Input:** Attributes **Output:** Understanding
Examples: Noise removal, image sharpening	**Examples:** Object recognition, segmentation	**Examples:** Scene understanding, autonomous navigation

A PROTOCOL WAS DEVELOPED IN MATLAB USING DIGITAL IMAGE PROCESSING FOR PREDICTING MASS OF WATER DROPLET ON A HORIZONTAL PLATE ON WHICH WATER WAS ARTIFICIALLY CONDENSED BY USING A PELTIAR MODULE TO EXPERIMENT CONDITIONS PREVAILING IN SPACE.

USE OF PELTIER MODULE:



Condensation plate
Peltier
Heat sink

Peltier module

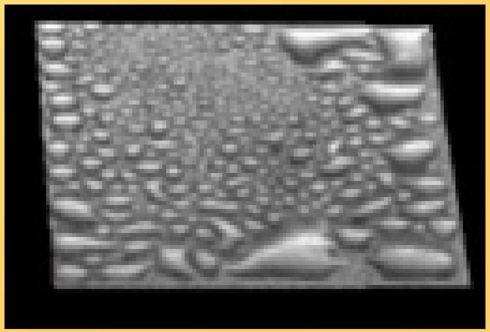
Current source

Current changes → Temperature of the plate changes → Water droplets could be produced

IMAGES OF CONDENSATION PLATES TAKEN AT INCREASING TIME INTERVALS HAVING INCREASING CONDENSATION:

a b c d e f g

Condensing plates with increasing water condensate droplets on the surface of the horizontal plate (a.0.5,b.0.7,c.0.9,d.1.0,e.1.7,f.1.8,g.2.3)



After negating Image

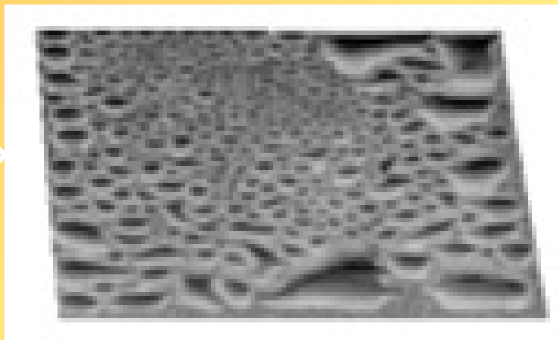
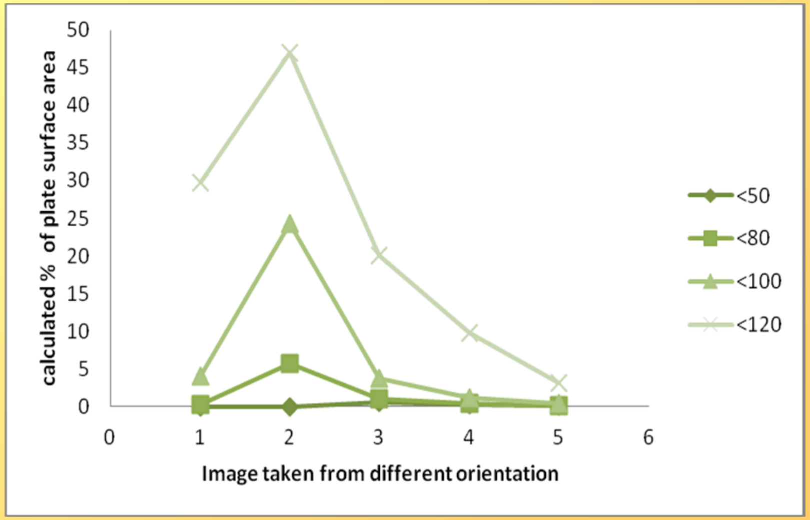
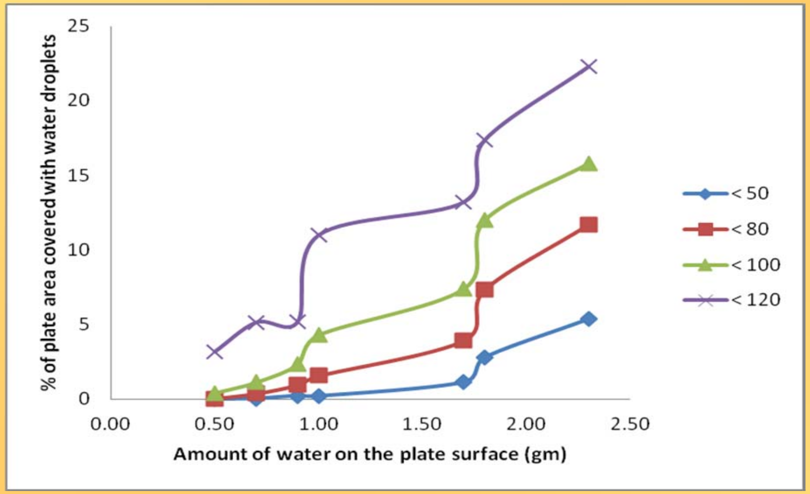


Image of modification from original to modified negative image.



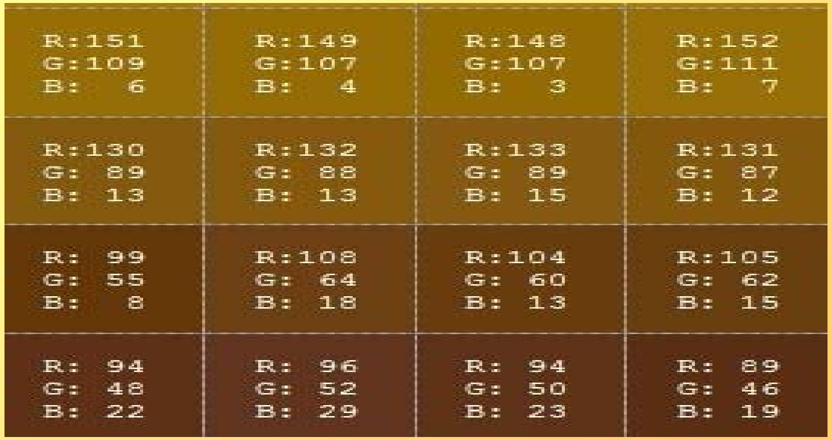
Plot versus Image taken from different orientations versus percentage of the calculated plate surface area.



The plot of amount of water on the plate surface in gms versus percentage of plate surface covered with water droplets for different black pixels values.

TO HAVE AN EXACT AND ABSOLUTE KNOWLEDGE ABOUT THE AMOUNT OF THE WATER THE AREA MUST BE CALCULATED OF THE PART OF THE DROPLET COVERING THE PLATE WHICH IS DONE HERE WITH THE HELP OF THRESHOLDING:

•In doing so transparency of the water drop was a difficulty which was faced, so colored droplets were used first to check the results of the algorithm.
•As the transparent water drops have a change only at the boundary and the interior and exterior does not makes a difference.



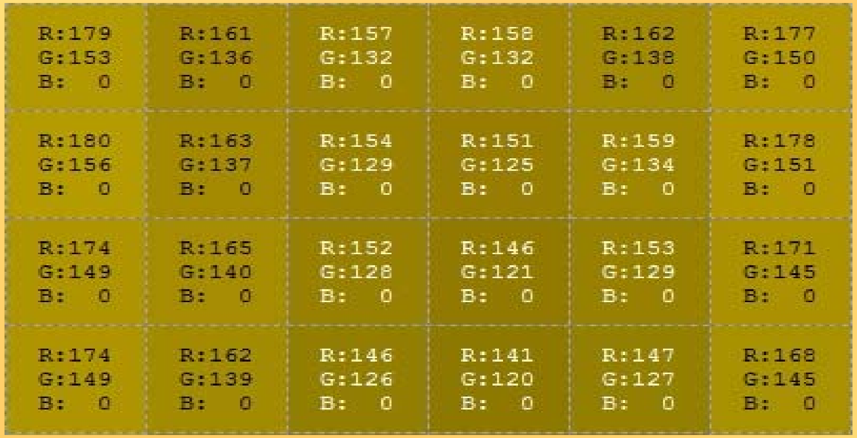
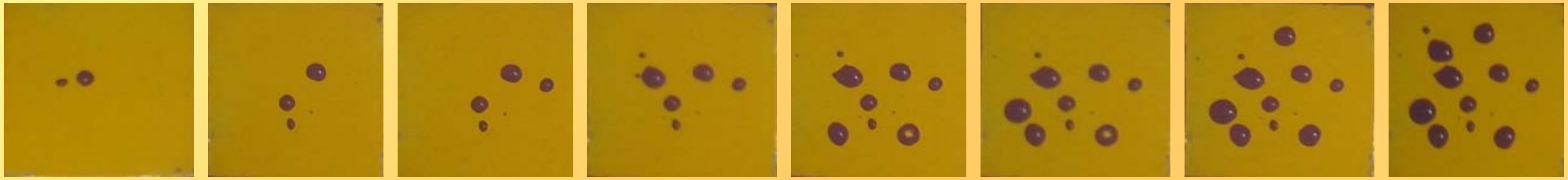


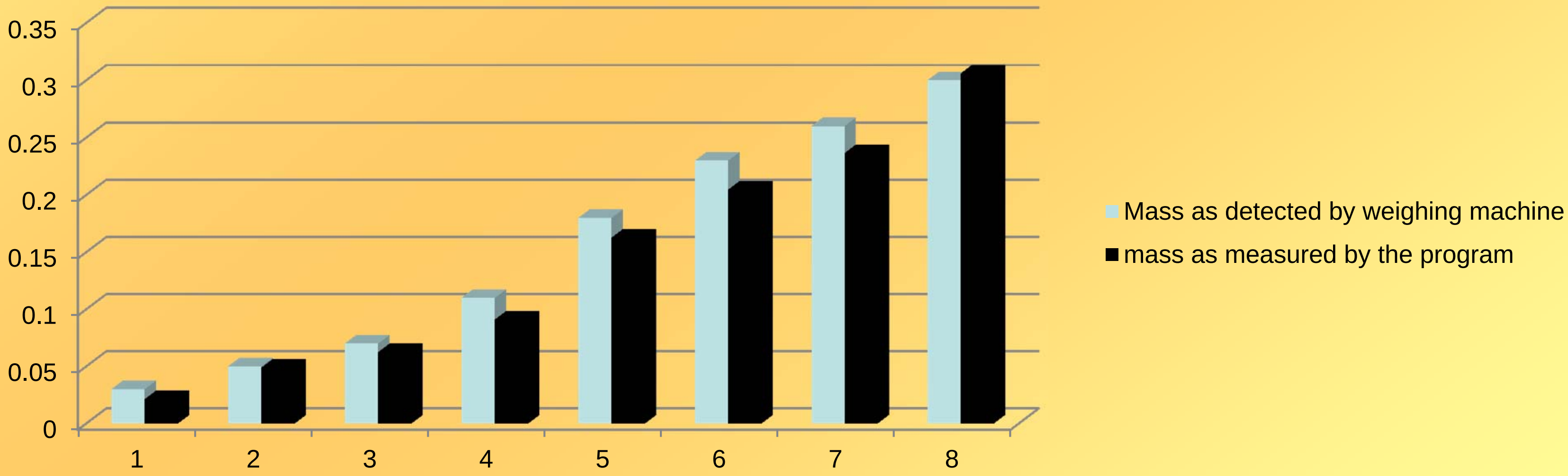
Image showing how transparency of water droplet is a problem in image processing to separate the water droplet from the background

Image showing the binarization of image of plate containing colored drops.

IMAGES AND RESULTS OF COLORED WATER DROPLETS:



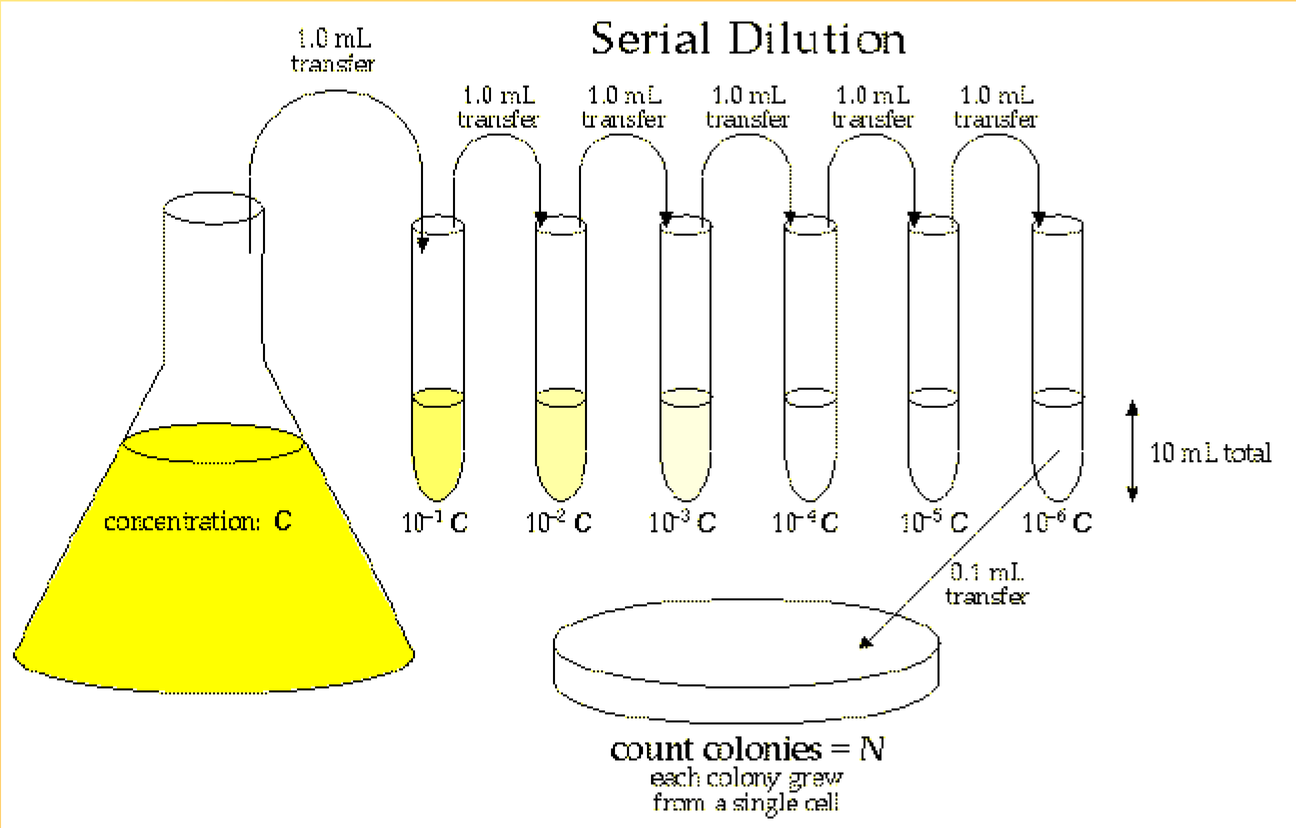
Increasing colored water droplets on the surface of a horizontal plate(a.0.03, b.0.05, c.0.07, d.0.11, e.0.18, f.0.23, g.0.26, h.0.3)



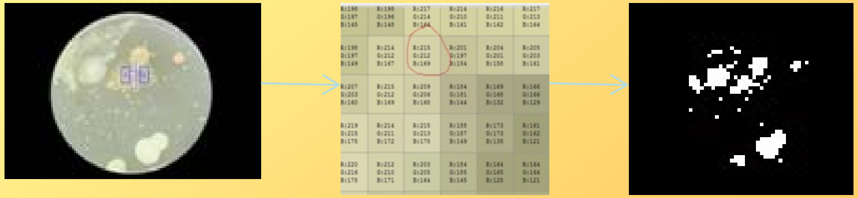
ESTIMATION OF BIOMASS:

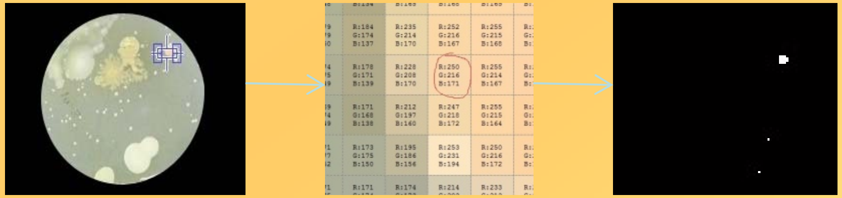
- For estimation of biomass, growth of the biomass was done on a semi-solid surface (agar) just to mimic the substrate bed of the solid-state fermenter to see the results of the program.
- This can help us to see the difference in the biomass when physical condition like water-activity and temperature would be differed so that these conditions could be optimized and production could be maximized.
- As industries need to maximize there production this could be a useful technique.

After serial dilution the soil sample was plated on the semi-solid nutrient agar poured in petri plates



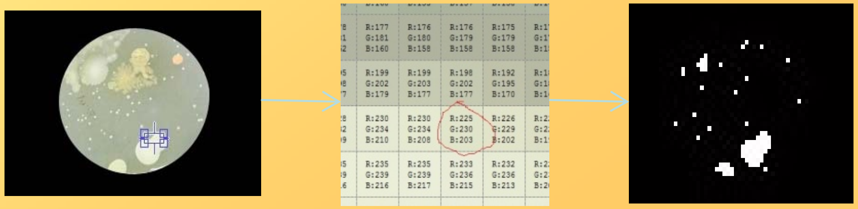
Images were taken from the digital camera which was processed as shown below in MATLAB using image processing:





a. whole culture

b. Isolate1



c. Isolate 2

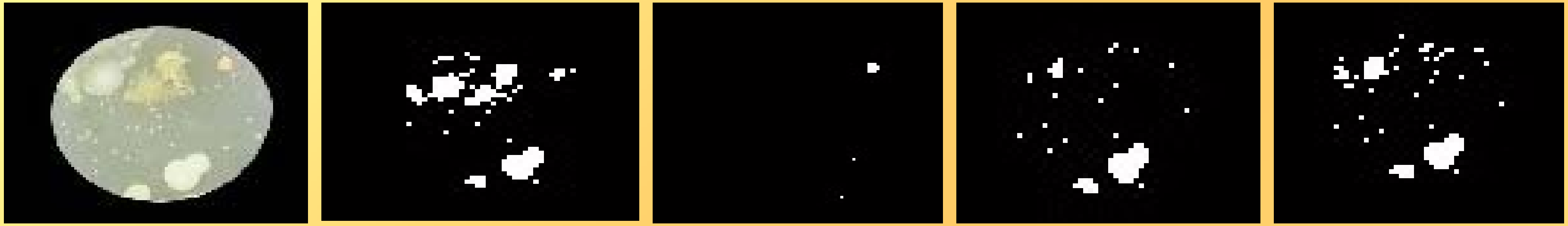
d. Isolate(2+3)

The image of the plate was taken .

Threshold value was found for every isolate by enlarging the pixel values of the image which helps us to know the pixel value at the boundary of that isolate.

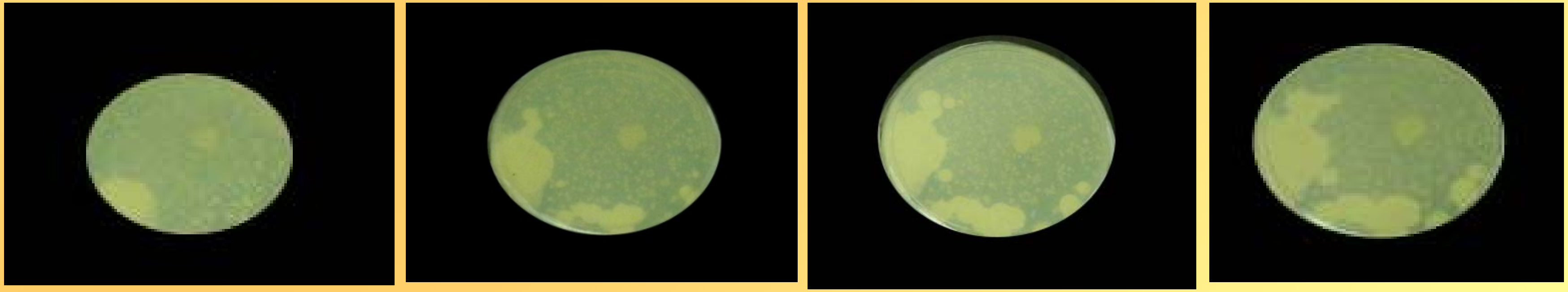
You can see above the resultant binarized image.

Images showing a comparision between the cultures of different isolates and its segmented area



a: Original Image, b: Thresholded image (whole culture), c: Thresholded image (Isolate 1), d: Thresholded image (Isolate 2), e: Thresholded image (Isolate 2+3).

Images showing the growth of biomass with the incubation time for validating the results of program:



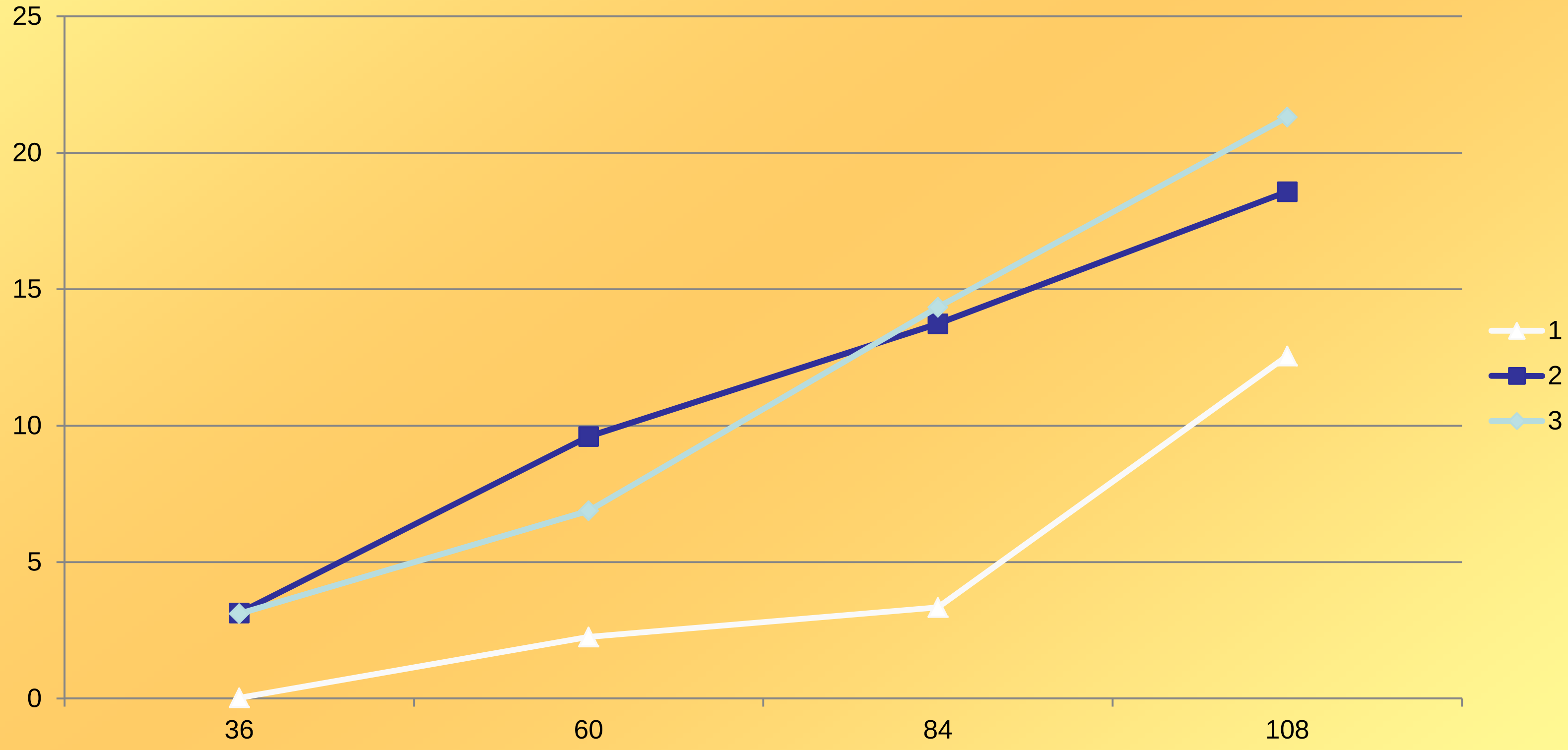
a.Original image

b.After 24 hrs incubation

c.After 48 hrs incubation

d. After 24 hrs incubation

GRAPH SHOWING THAT WITH THE INCREASE IN INCUBATION TIME THE AREA OF BIOMASS GROWTH ALSO INCREASES WHICH VERIFIES THE PROGRAM:



Thank you