

# Early breast cancer detection by simulated phantom X ray imaging on GATE

David Jurado

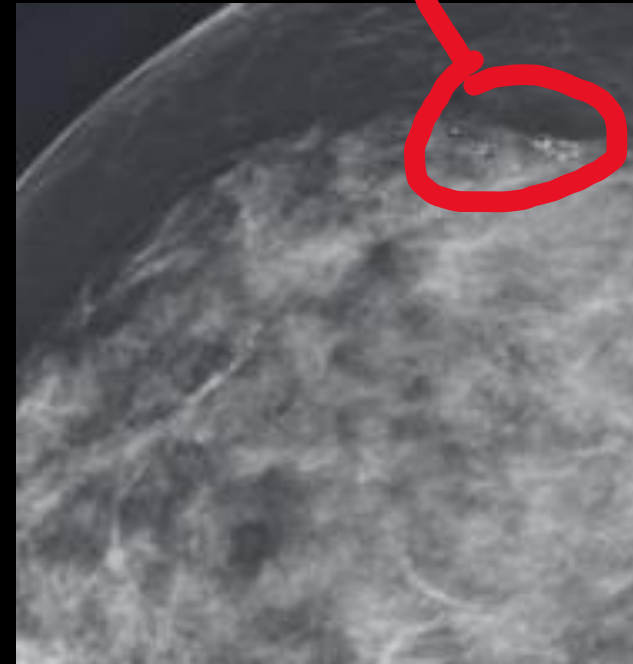
December 14, 2021

# Why is early breast cancer detection important?

- There is no known natural cure for breast cancer
- Primary prevention is still unclear
- Early detection makes therapy more effective, reducing mortality

# What are we looking for?

Masses

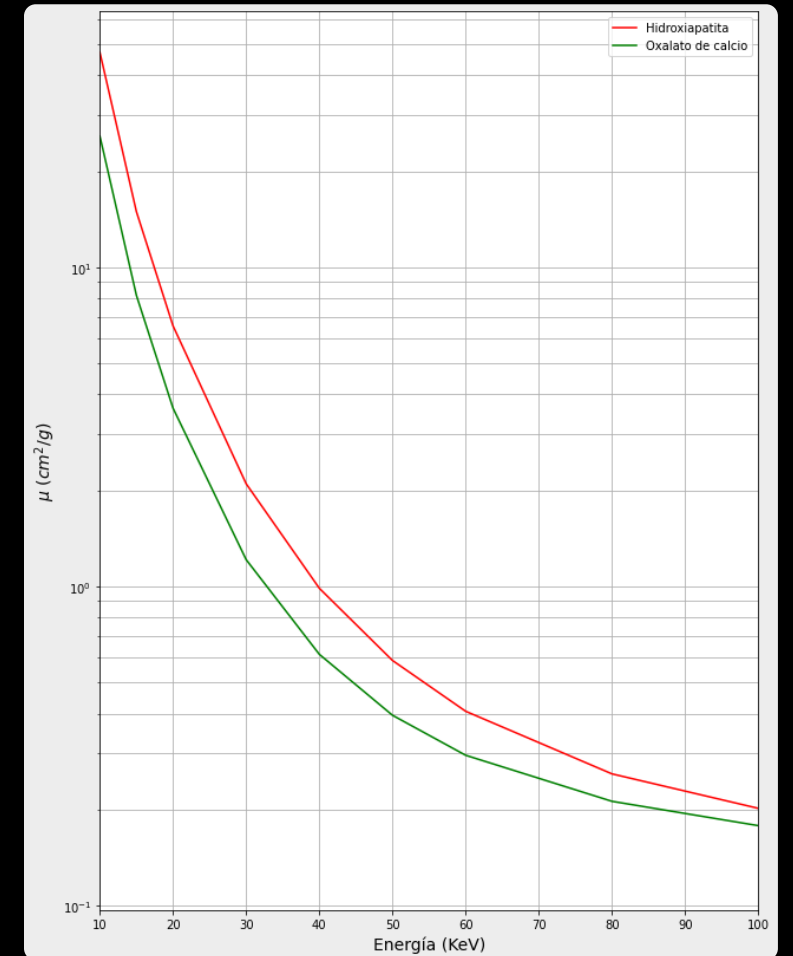


Microcalcifications

R. Vijayarajeswari. *Classification of mammogram for early detection of breast cancer using SVM classifier and Hough transform*

# Let's focus on microcalcifications...

- Small deposits ( $r < 500 \mu m$ ) of calcium that are either:
  - Type I: Hidroxiapatite  $Ca_5(PO_4)_3(OH)$
  - Type II: Calcium oxalate  $CaC_2O_4$



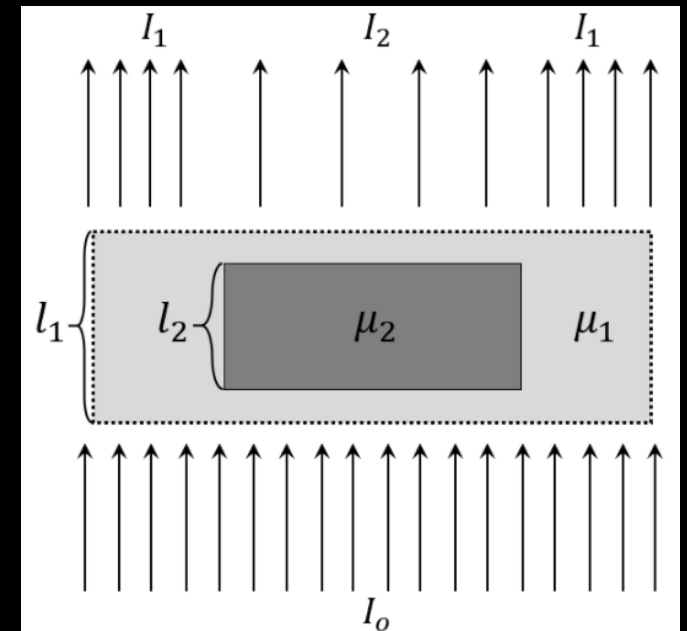
# Let's focus on microcalcifications...

- In the energy range of mammograms  $10\text{ kVp} \sim 50\text{ kVp}$  contrast within type I and II calcifications is limited

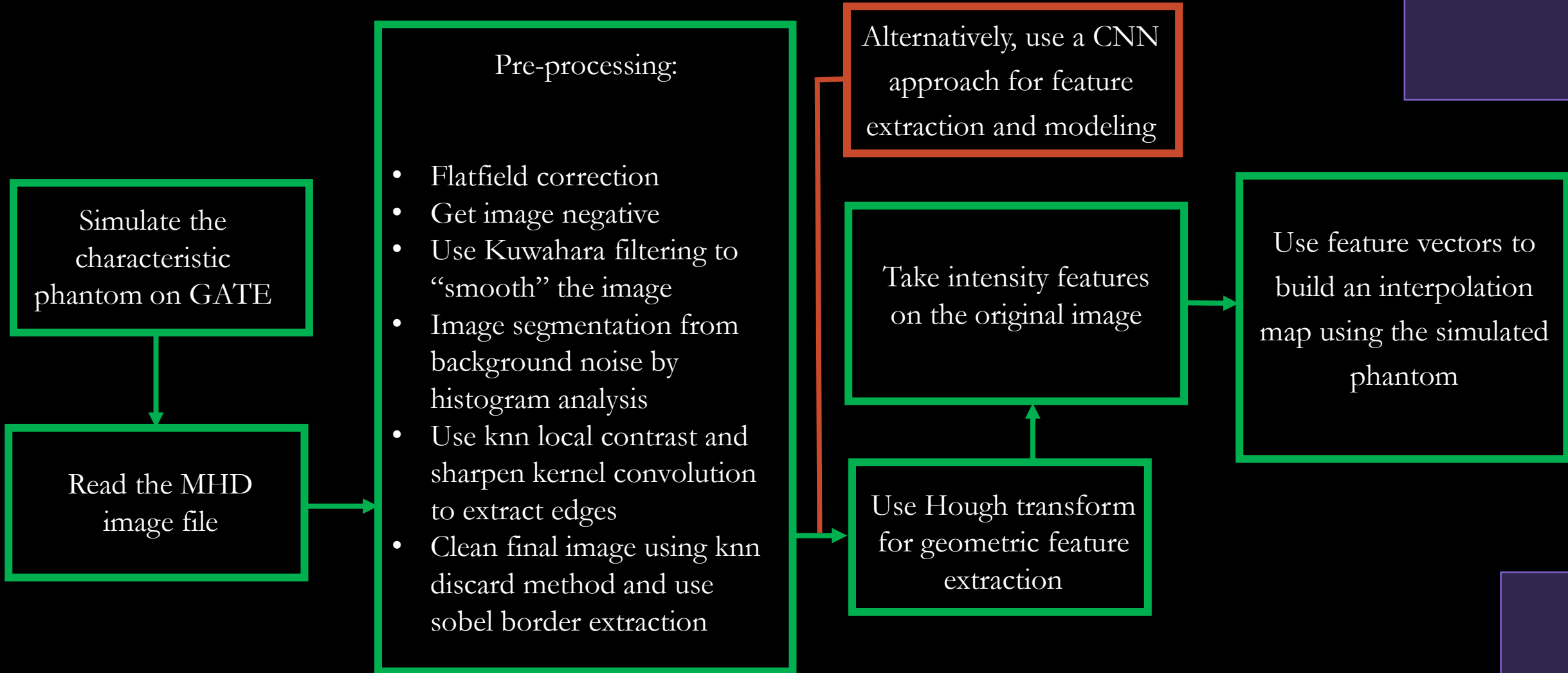
$$I_1 = I_0 e^{-\mu l_1}$$

$$I_2 = I_1 \text{Exp}(-\mu_1(l_1 - l_2)) \cdot \text{Exp}(-\mu_2 l_2)$$

$$C = \frac{I_1 - I_2}{I_1} = 1 - \text{Exp}(-R_2(\Delta\mu))$$

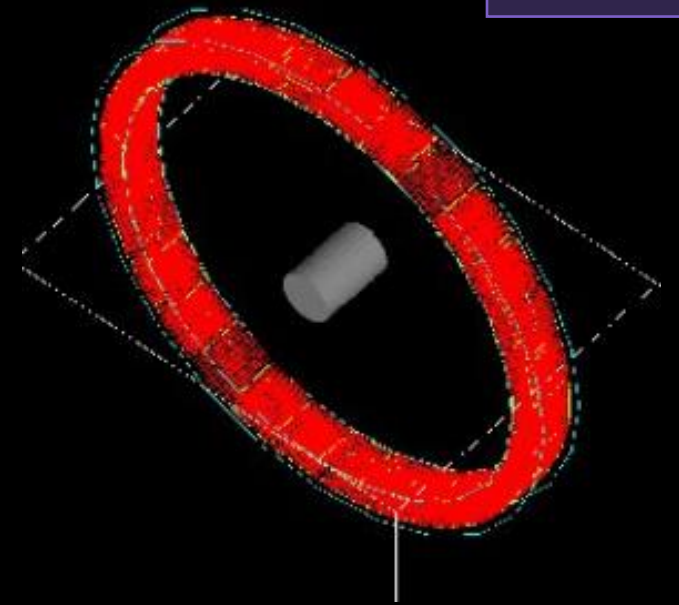


# Now, how do we approach this problem?



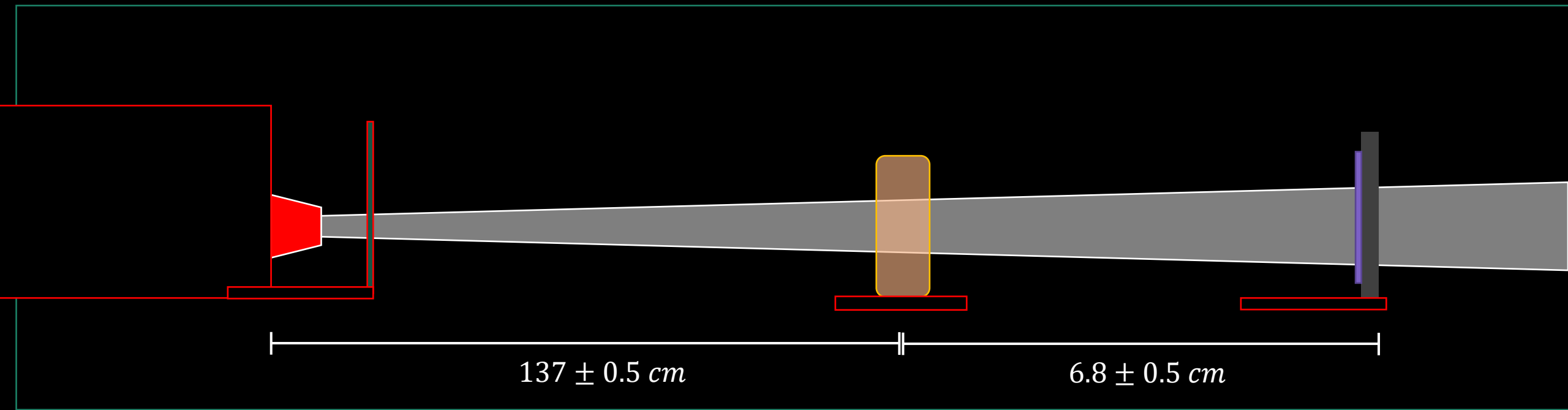
# What is GATE ?

- GATE is an open-source software specialized on medical imaging monte carlo simulations.
- It is built under the Geant4 particle physics library with a C++ architecture.
- supports for PET, SPECT, CT, Radiotherapy and others.



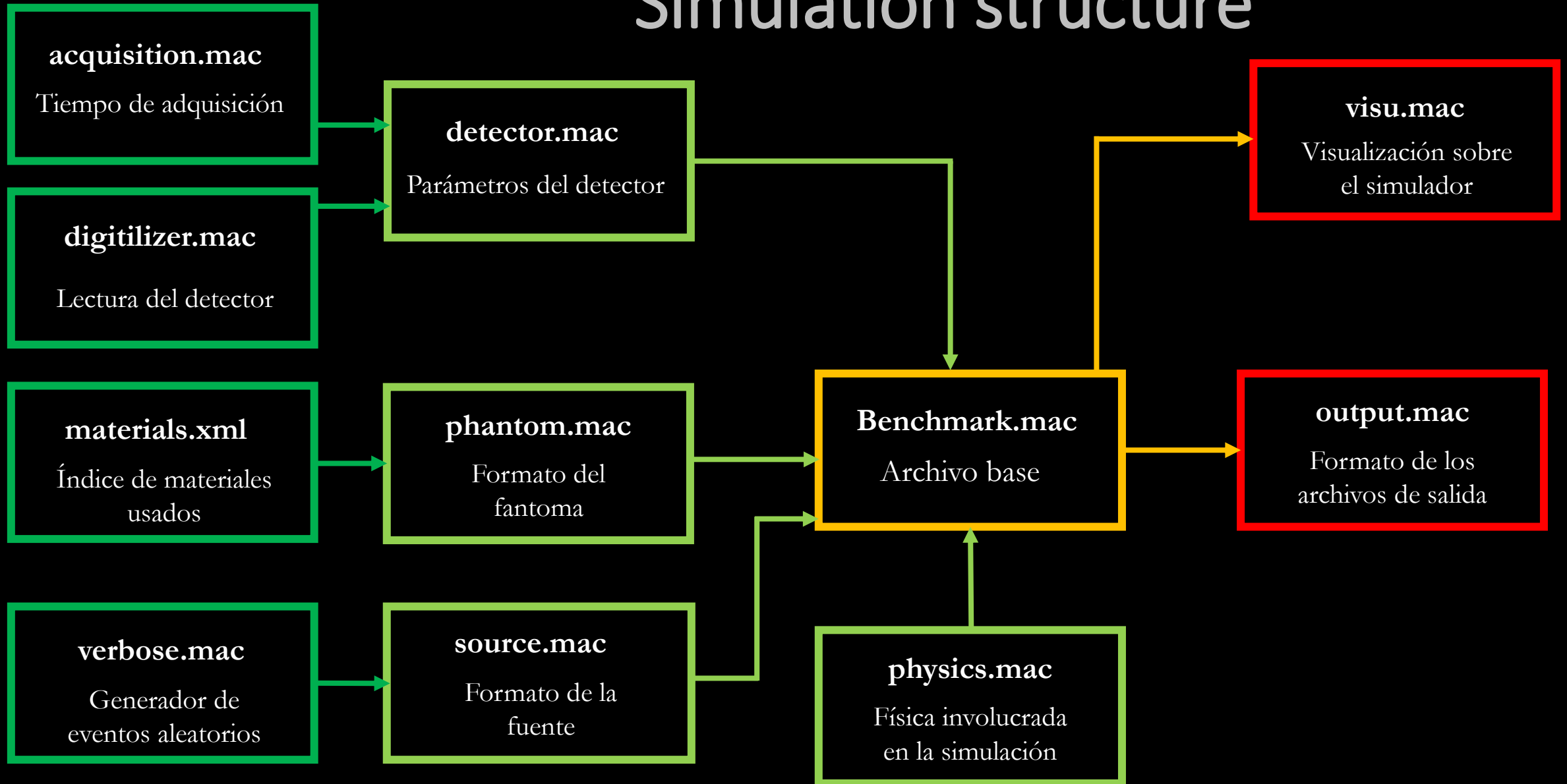
Jan S, Santin G, Strul D, et al. GATE: a simulation toolkit for PET and SPECT. *Phys Med Biol*.

# Virtual mammogram setup





# Simulation structure

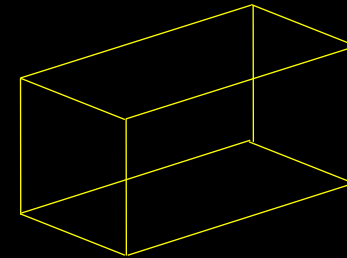


## phantom.mac

Formato del  
fantoma

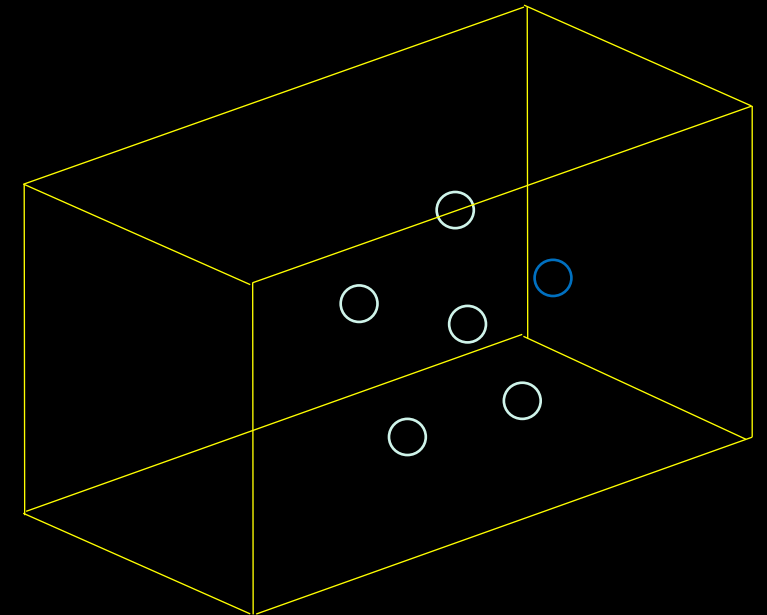
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#####  
  
/gate/world/daughters/name Contenedor  
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/gate/Contenedor/geometry/setXLength 4 cm  
/gate/Contenedor/geometry/setYLength 2 cm  
/gate/Contenedor/geometry/setZLength 2 cm  
/gate/Contenedor/setMaterial Breast  
/gate/Contenedor/vis/forceWireframe  
/gate/Contenedor/vis/setColor blue  
  
#####  
# fantoma #  
#####  
  
/gate/Contenedor/daughters/name crystalHAS  
/gate/Contenedor/daughters/insert sphere  
/gate/crystalHAS/placement/setTranslation 4.5 0 0 mm  
/gate/crystalHAS/geometry/setRmin 0 mm  
/gate/crystalHAS/geometry/setRmax 0.24 mm  
/gate/crystalHAS/geometry/setPhiStart 0 deg  
/gate/crystalHAS/geometry/setDeltaPhi 360 deg  
/gate/crystalHAS/geometry/setThetaStart 0 deg  
/gate/crystalHAS/geometry/setDeltaTheta 360 deg  
/gate/crystalHAS/setMaterial HA  
/gate/crystalHAS/vis/forceWireframe  
/gate/crystalHAS/vis/setColor red  
  
/gate/crystalHAS/repeaters/insert ring  
/gate/crystalHAS/ring/setRepeatNumber 5  
/gate/crystalHAS/ring/setPoint1 0. 0. 10. mm  
/gate/crystalHAS/ring/setPoint2 0. 0. 0. mm
```

```
#####  
# Contenedor #  
#####  
  
/gate/world/daughters/name Contenedor  
/gate/world/daughters/insert box  
/gate/Contenedor/placement/setTranslation 0.0 0.0 0.0 cm  
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/gate/Contenedor/geometry/setYLength 2 cm  
/gate/Contenedor/geometry/setZLength 2 cm  
/gate/Contenedor/setMaterial Breast  
/gate/Contenedor/vis/forceWireframe  
/gate/Contenedor/vis/setColor blue
```



```
#####  
# fantoma #  
#####
```

```
/gate/Contenedor/daughters/name crystalHAS  
/gate/Contenedor/daughters/insert sphere  
/gate/crystalHAS/placement/setTranslation 4.5 0 0 mm  
/gate/crystalHAS/geometry/setRmin 0 mm  
/gate/crystalHAS/geometry/setRmax 0.24 mm  
/gate/crystalHAS/geometry/setPhiStart 0 deg  
/gate/crystalHAS/geometry/setDeltaPhi 360 deg  
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/gate/crystalHAS/ring/setPoint2 0. 0. 0. mm
```

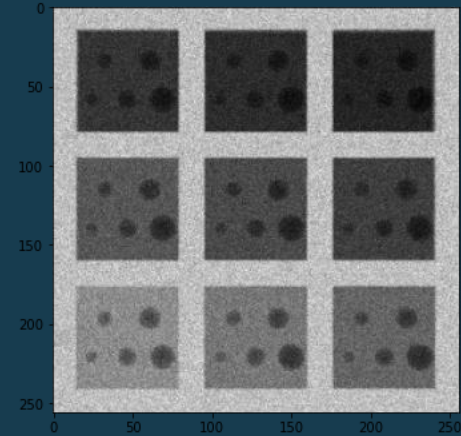
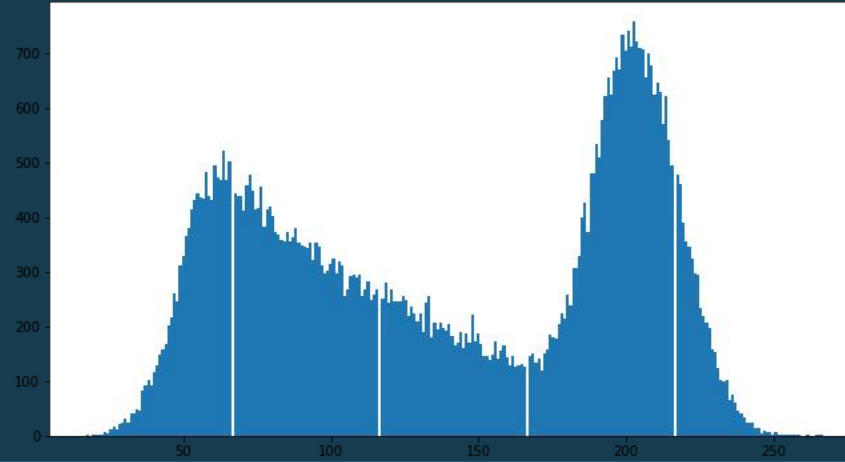


# Image Pre-processing

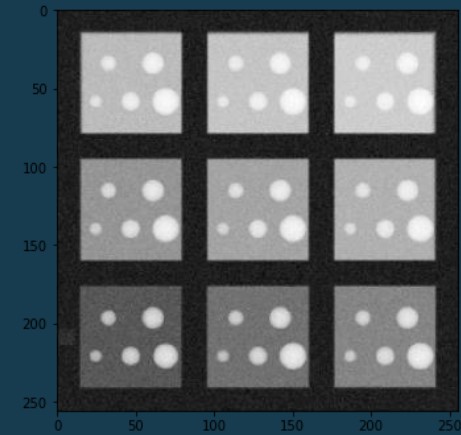
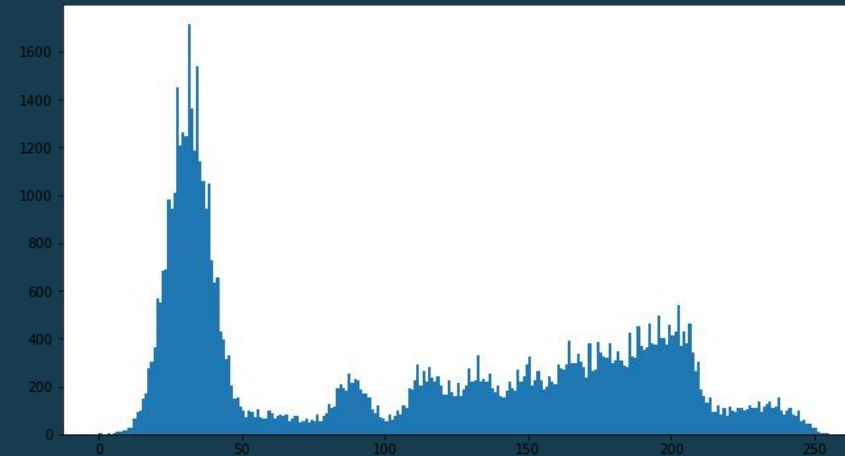
## Pre-processing:

- Flatfield correction
- Get image negative
- Use Kuwahara technique to “smooth” the image
- Image segmentation from background noise by histogram analysis
- Use knn local contrast and sharpen kernel convolution to extract edges
- Clean final image using knn discard method

Load image



Flatfield +  
negative

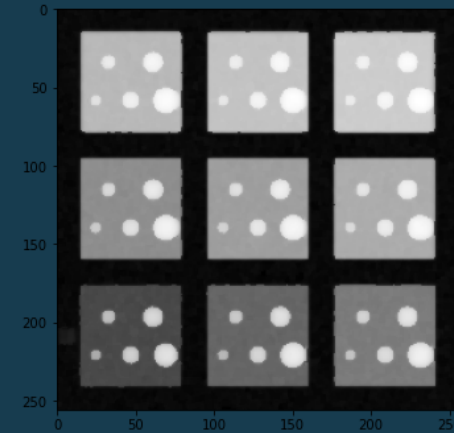
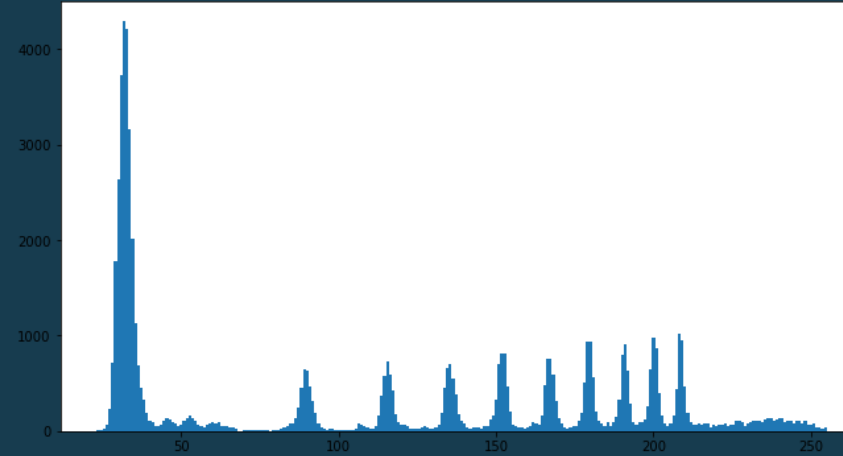


# Image Pre-processing

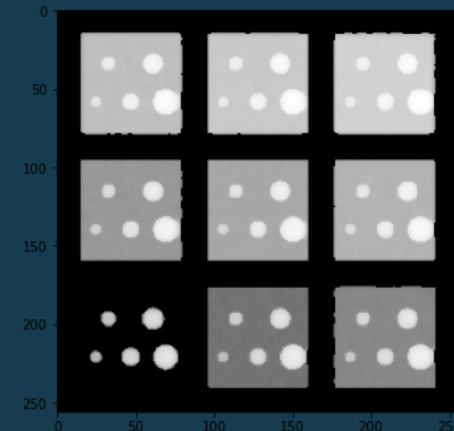
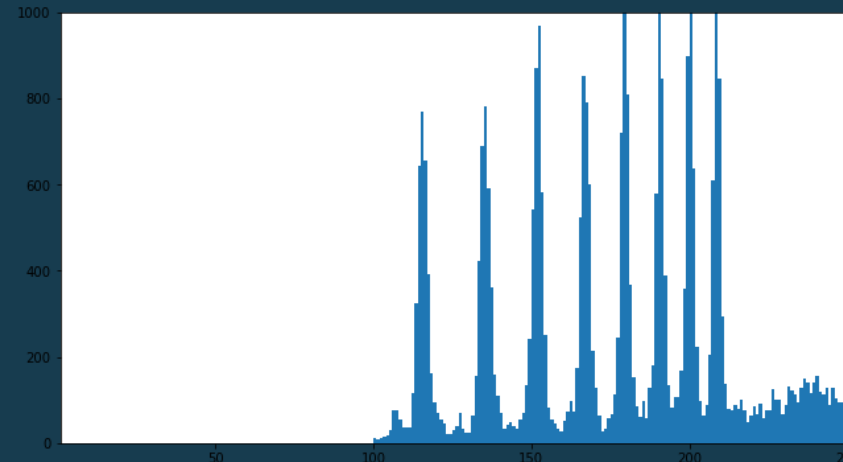
## Pre-processing:

- Flatfield correction
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- Use Kuwahara filtering to “smooth” the image
- Image segmentation from background noise by histogram analysis
- Use knn local contrast and sharpen kernel convolution to extract edges
- Clean final image using knn discard method

Kuwahara filtering



Remove and scale

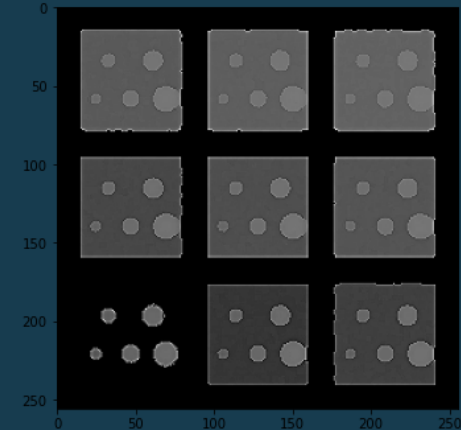
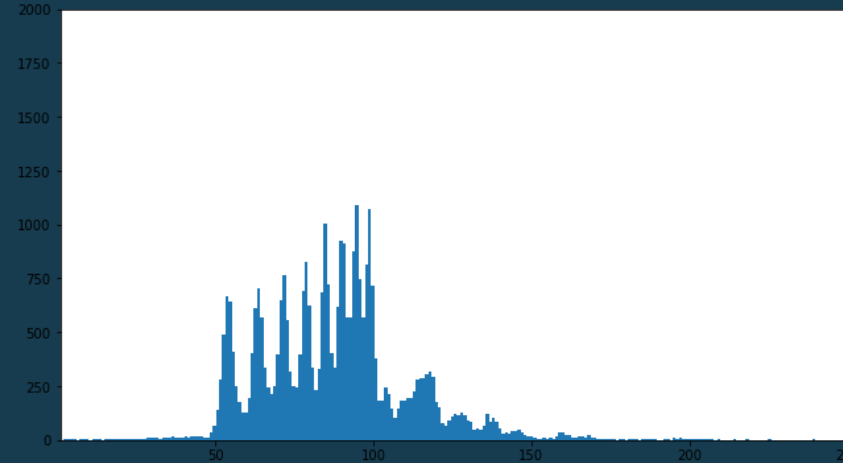


# Image Pre-processing

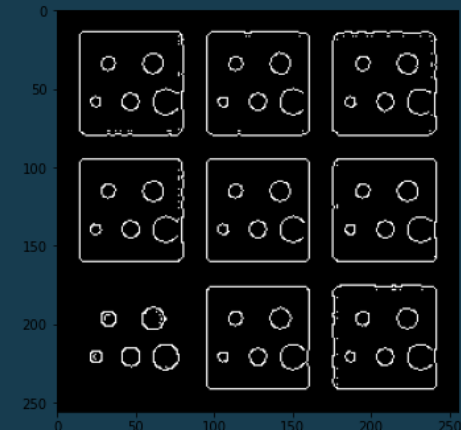
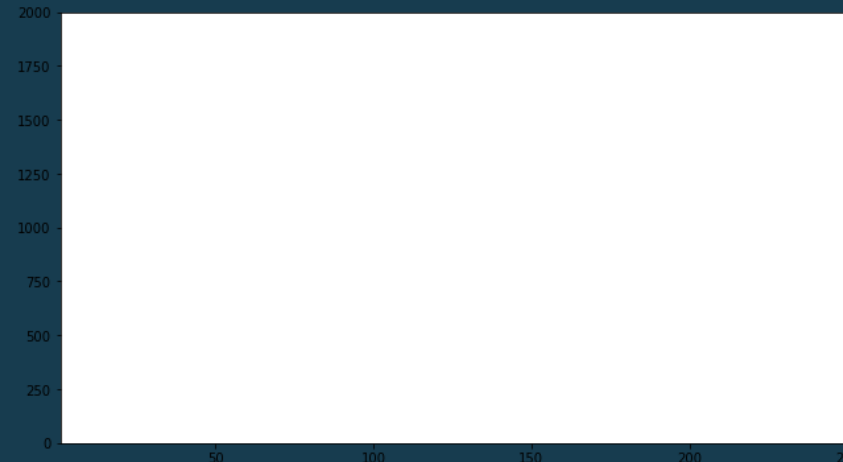
## Pre-processing:

- Flatfield correction
- Get image negative
- Use Kuwahara filtering to “smooth” the image
- Image segmentation from background noise by histogram analysis
- Use knn local contrast and sharpen kernel convolution to extract edges
- Clean final image using knn discard method and use sobel border extraction

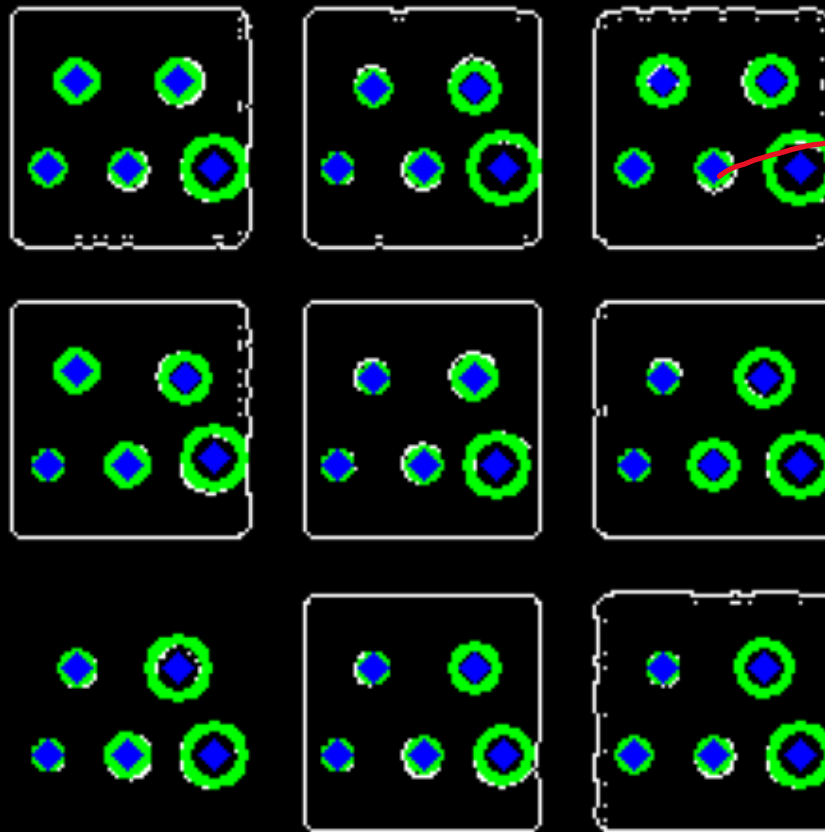
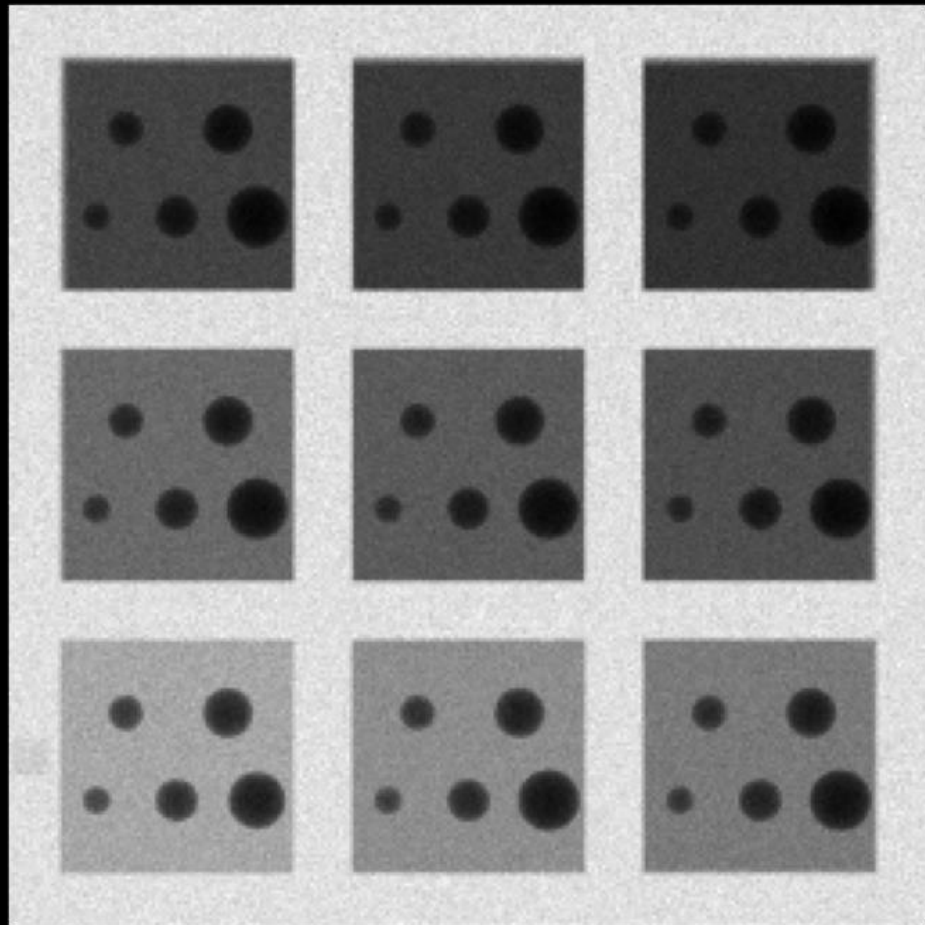
contrast+  
sharpen



Remove and  
scale



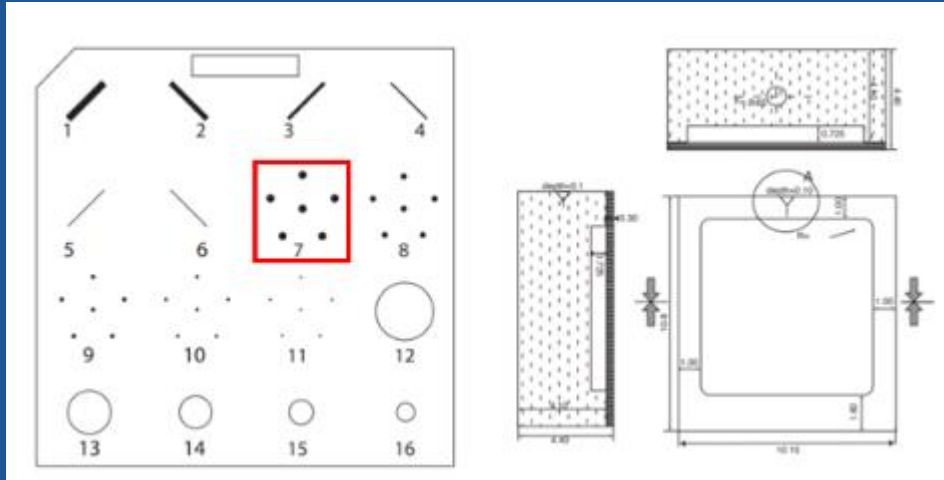
# Feature extraction By Hough transform



$$C_i = \begin{bmatrix} (x, y) \\ r \\ \bar{I}_r, \bar{I}_c \end{bmatrix}$$



# Fidelity test for a real mammogram



Real			Simulado		
Centro	Radio	$\bar{I}$	Centro	Radio	$\bar{I}$
(281, 62)	12	179.7	(310, 82)	14	186.1
(286,390)	11	186.7	(310,430)	12	189.0
(65,322)	15	176.0	(110,361)	13	187.8
(250,217)	14	176.8	(255,257)	14	185.7
( 74,122)	14	174.4	(110,146)	12	189.2
(426,225)	10	181.9	(438,254)	14	187.4

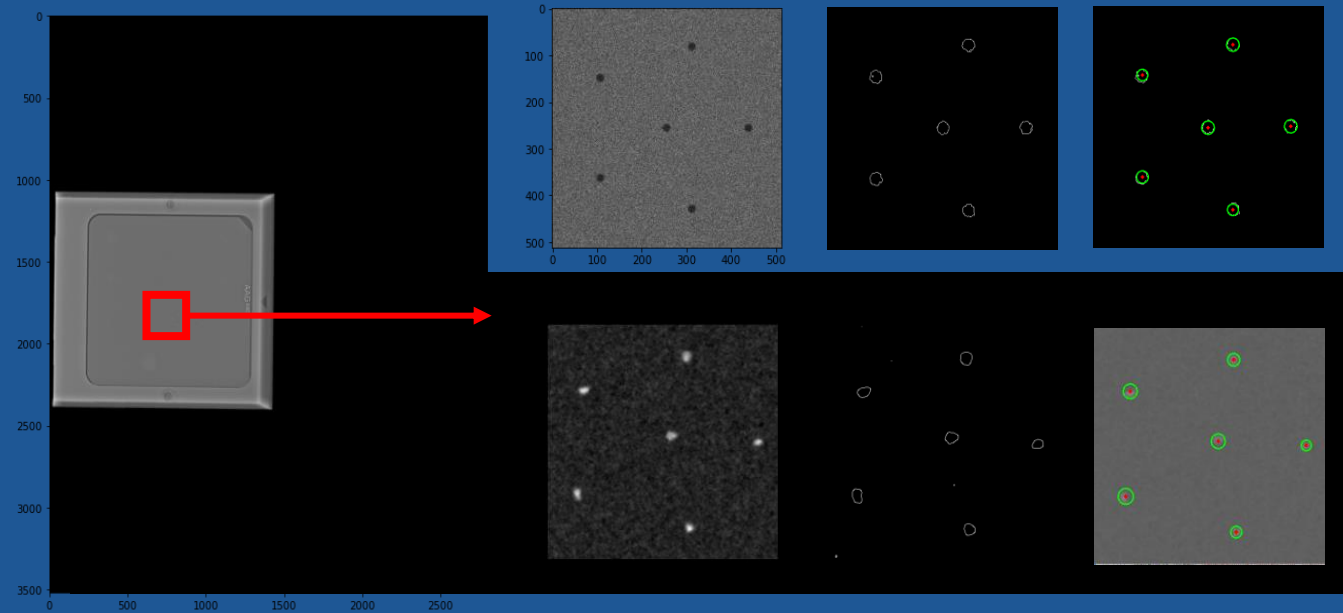


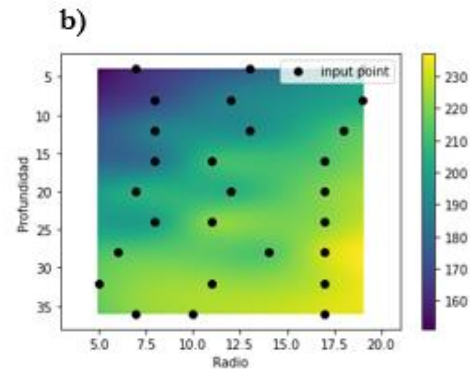
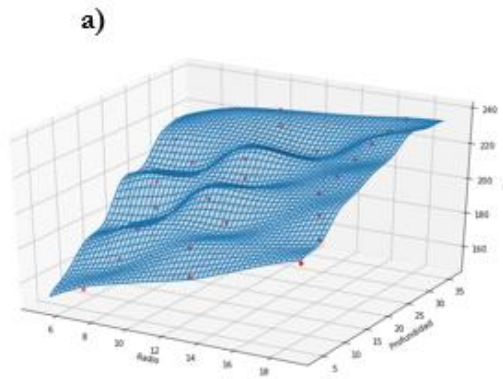
Imagen	Promedio	Varianza	Promedio detectado ( $\mu m \pm 24$ )	Error relativo porcentual
Real	12.66	3.86	303.84	8.5 %
Simulada	13.16	0.96	315.84	12.8 %

Number of events: 1.2 B. Breast phantom with PMMA tissue at 4 cm width , microspheres with diameter  $280 \mu m$ , X ray source with W anode, energy range between 21 y 28 keV

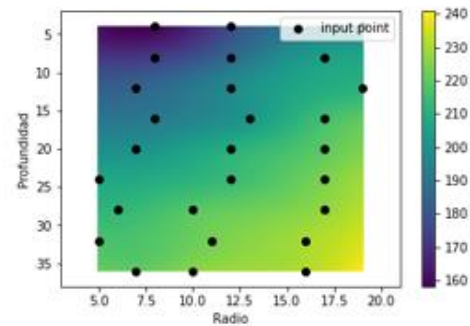
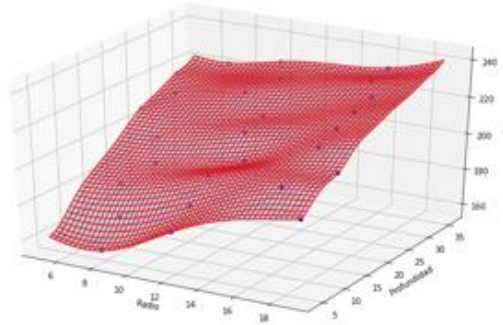


# Interpolation reconstruction

Hidroxiapatita

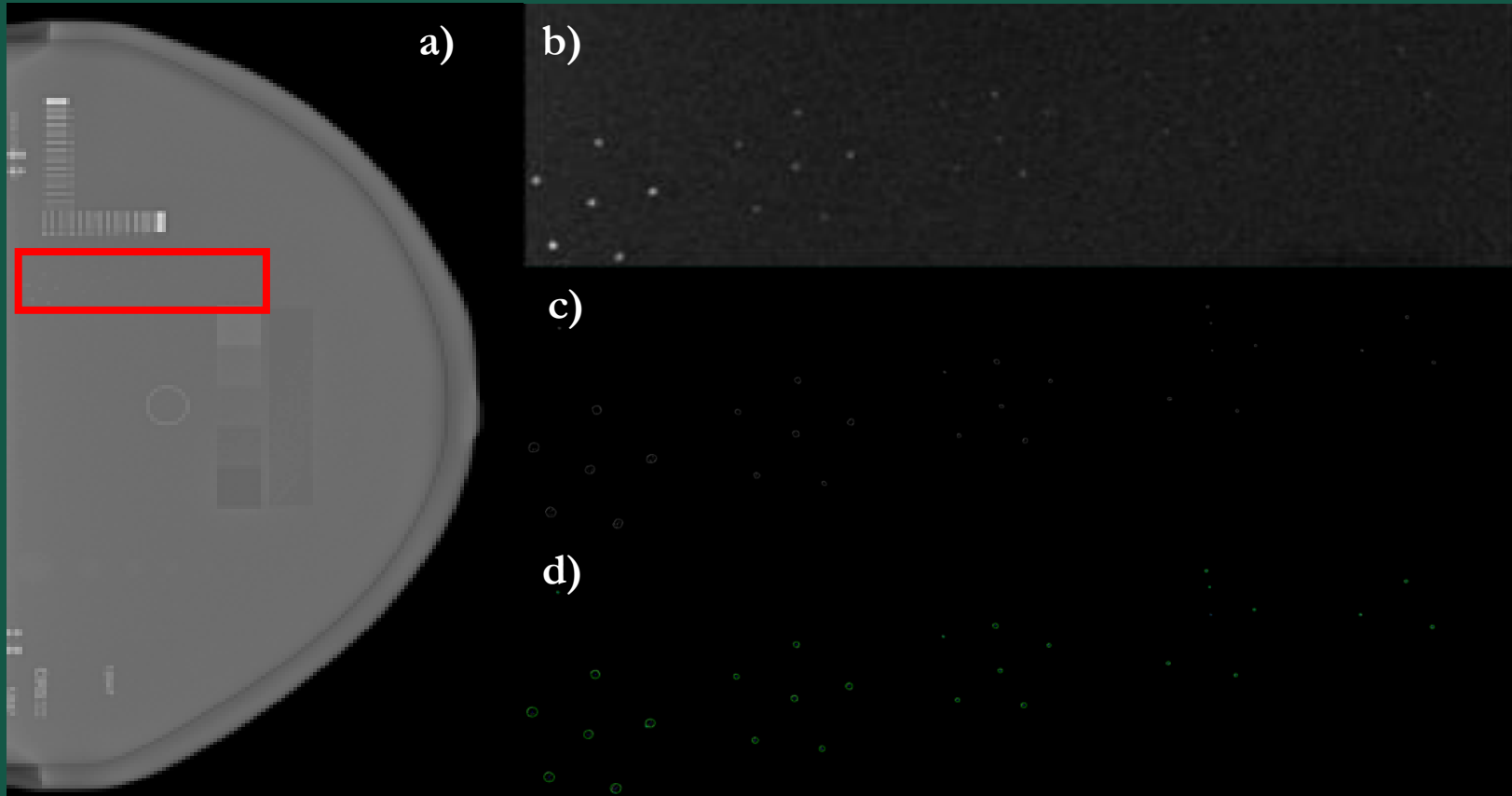


Oxalato de calcio

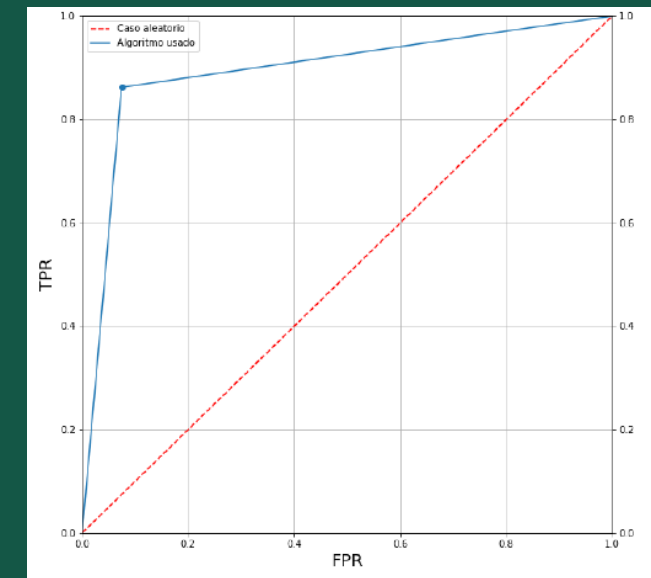


Orden	$\bar{I}$ medido	$H_I(r, d)$	Error relativo porcentual
1	163.6	163.5	0.1 %
2	226.3	229.9	1.6 %
3	217.2	211.9	2.4 %

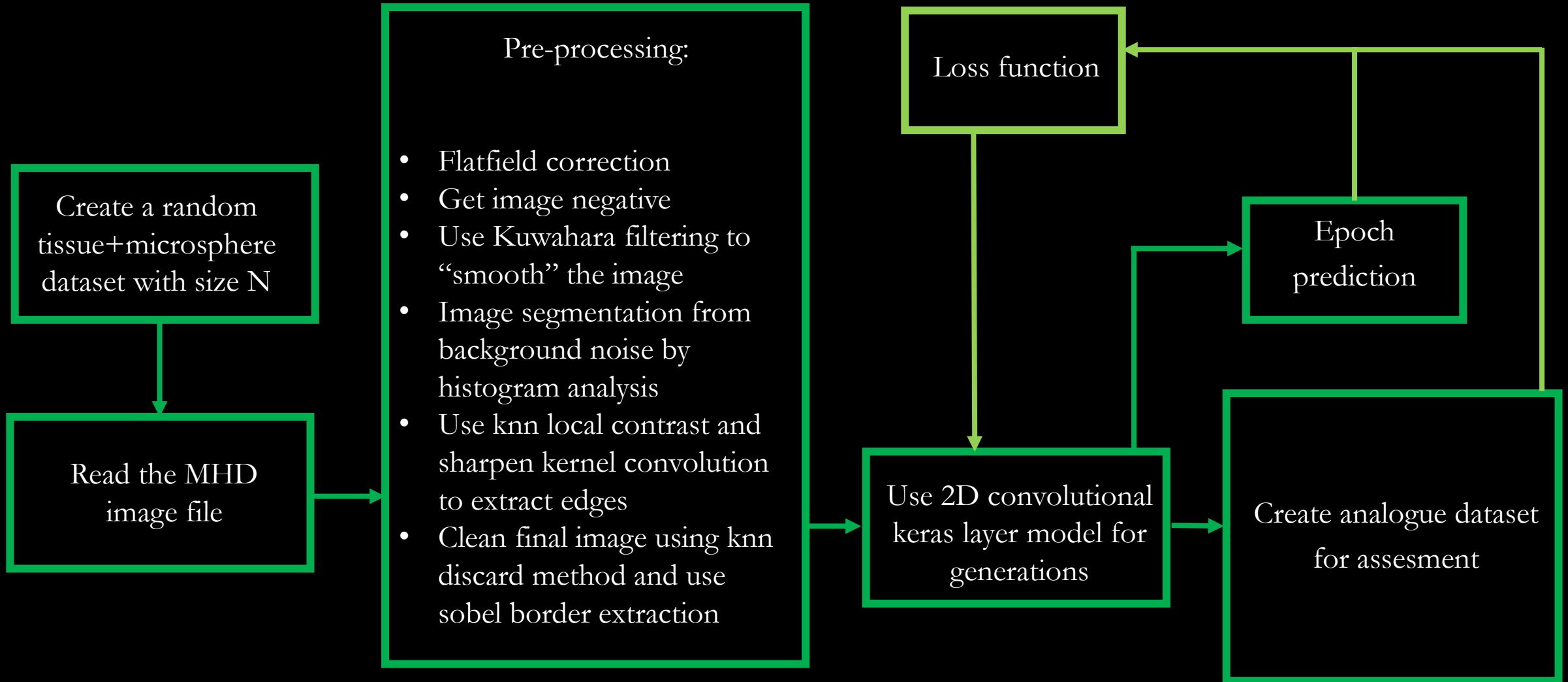
# Model Performance



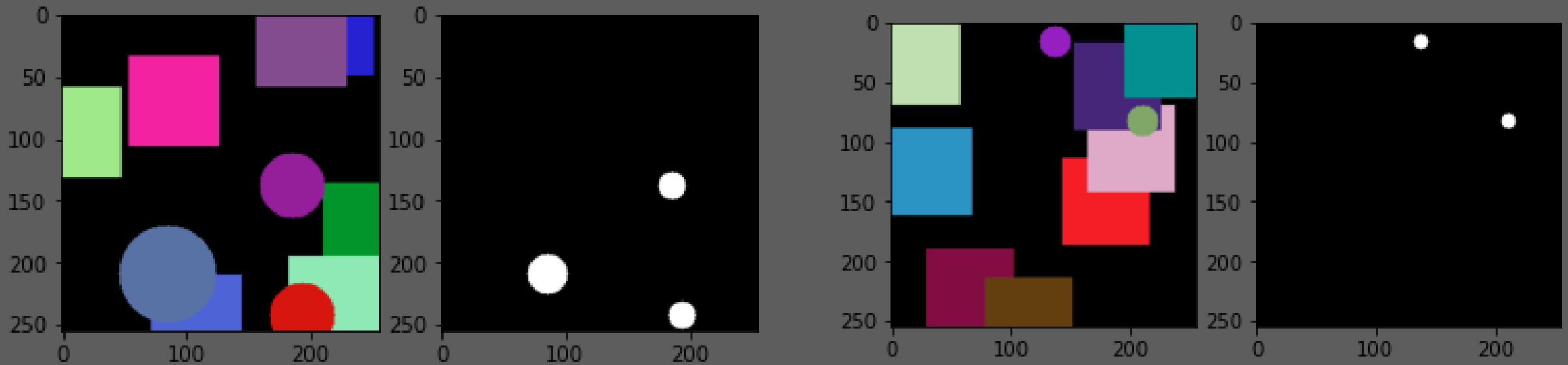
<b>Verdaderos Positivos</b>	25	
<b>Falsos Positivos</b>	2	
<b>Falsos Negativos</b>	4	
<b>Precisión</b>	<b>Sensibilidad</b>	<b>Puntaje F1</b>
0.9259	0.8620	0.8928



# CNN Alternative



# CNN Alternative



Muchas gracias