



# Una estrategia para la clasificación óptica de almendras

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Asesores

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2017













*Prunus dulcis*



Sonora



Solano



Nonpareil



Nonpareil 15



Mono



Carmel

Desmayo  
Largueta

Texas 126

Mission

Padre

Monterey

Butte

Price

Thompson



Marcona

Desmayo  
Rojo

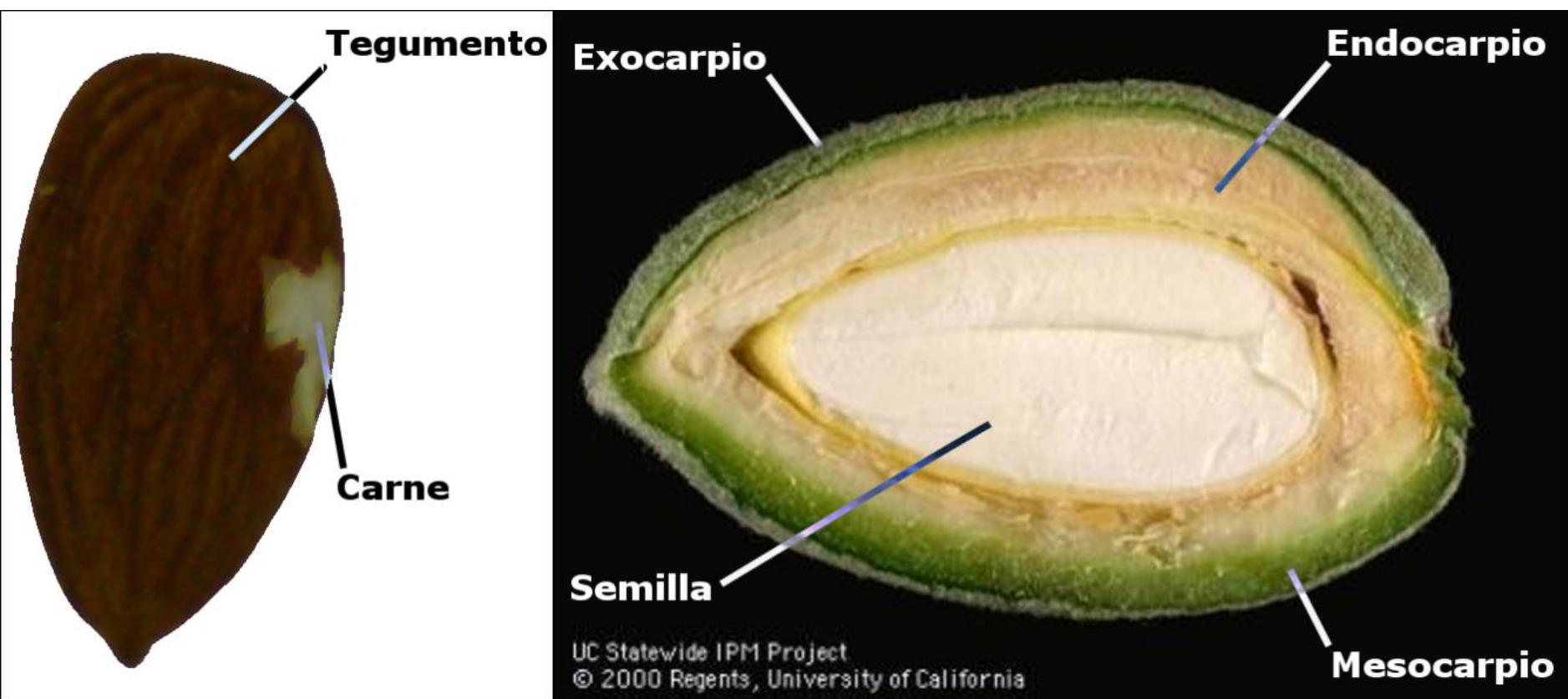
Guara

Ahumada, 2004  
Universidad de Chile









Cosecha

Limpieza

Clasificación

Descapotado

Pelado

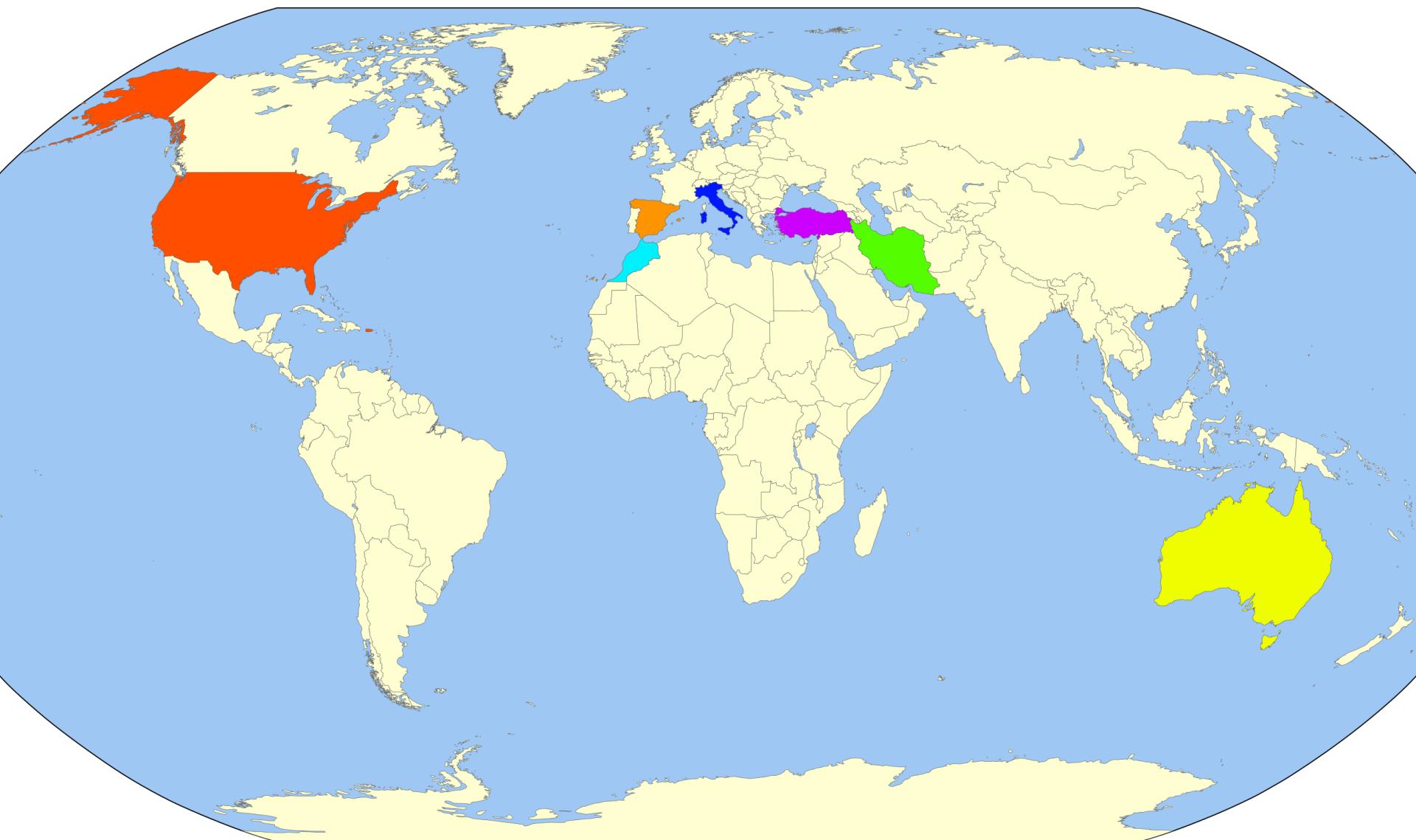




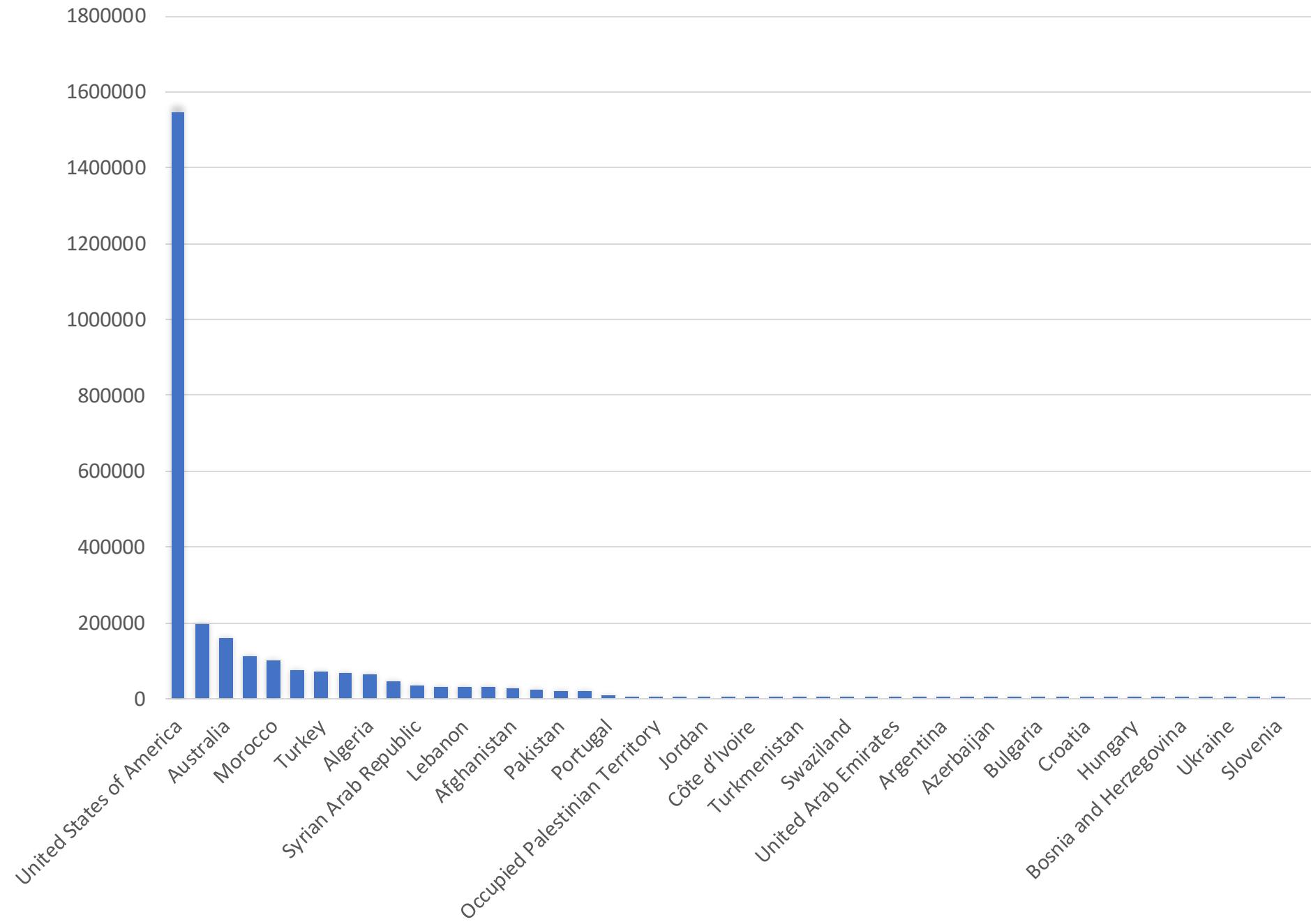




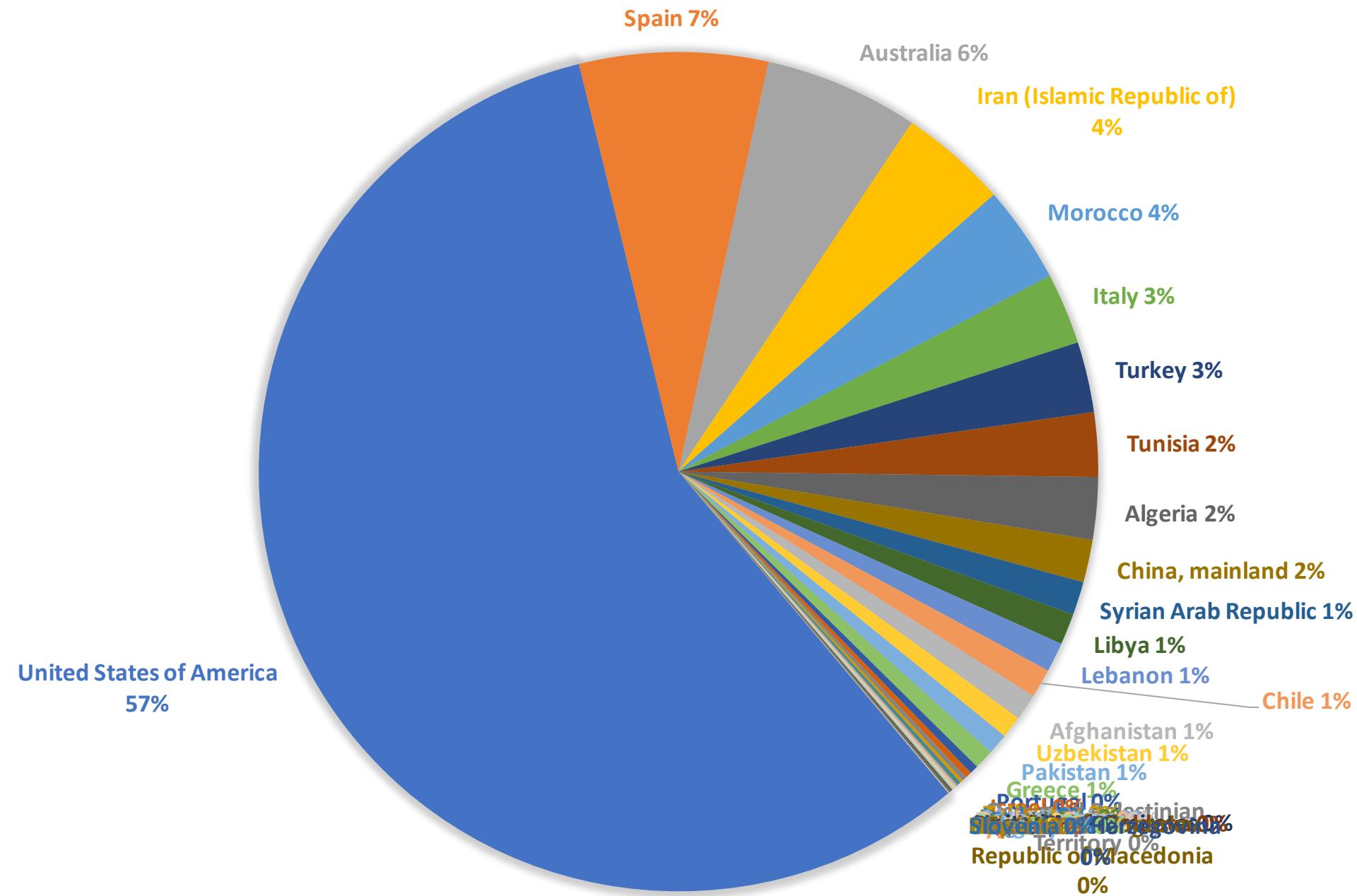


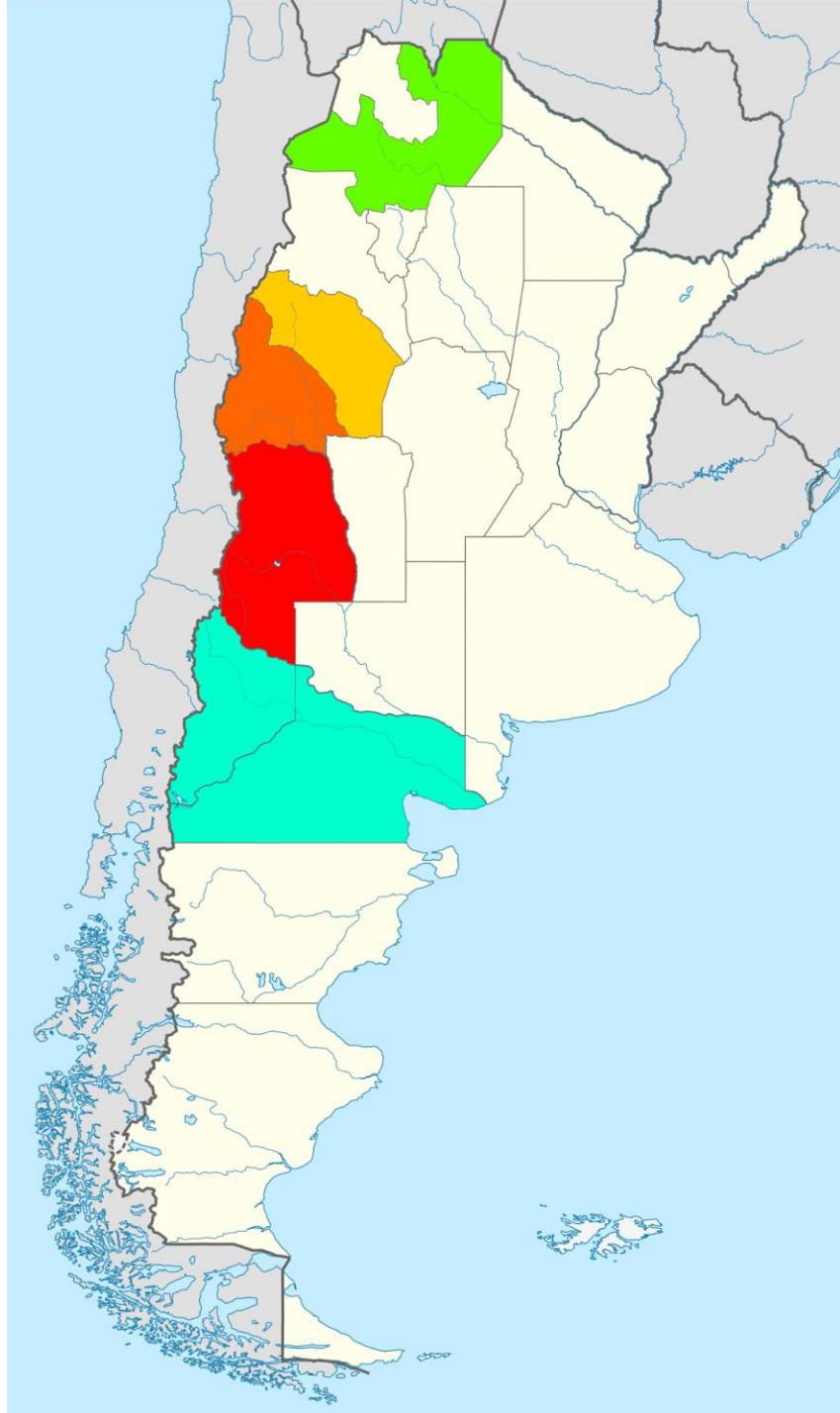


# PRODUCCIÓN DE ALMENDRAS CON CASCARA EN 2014 [TON]

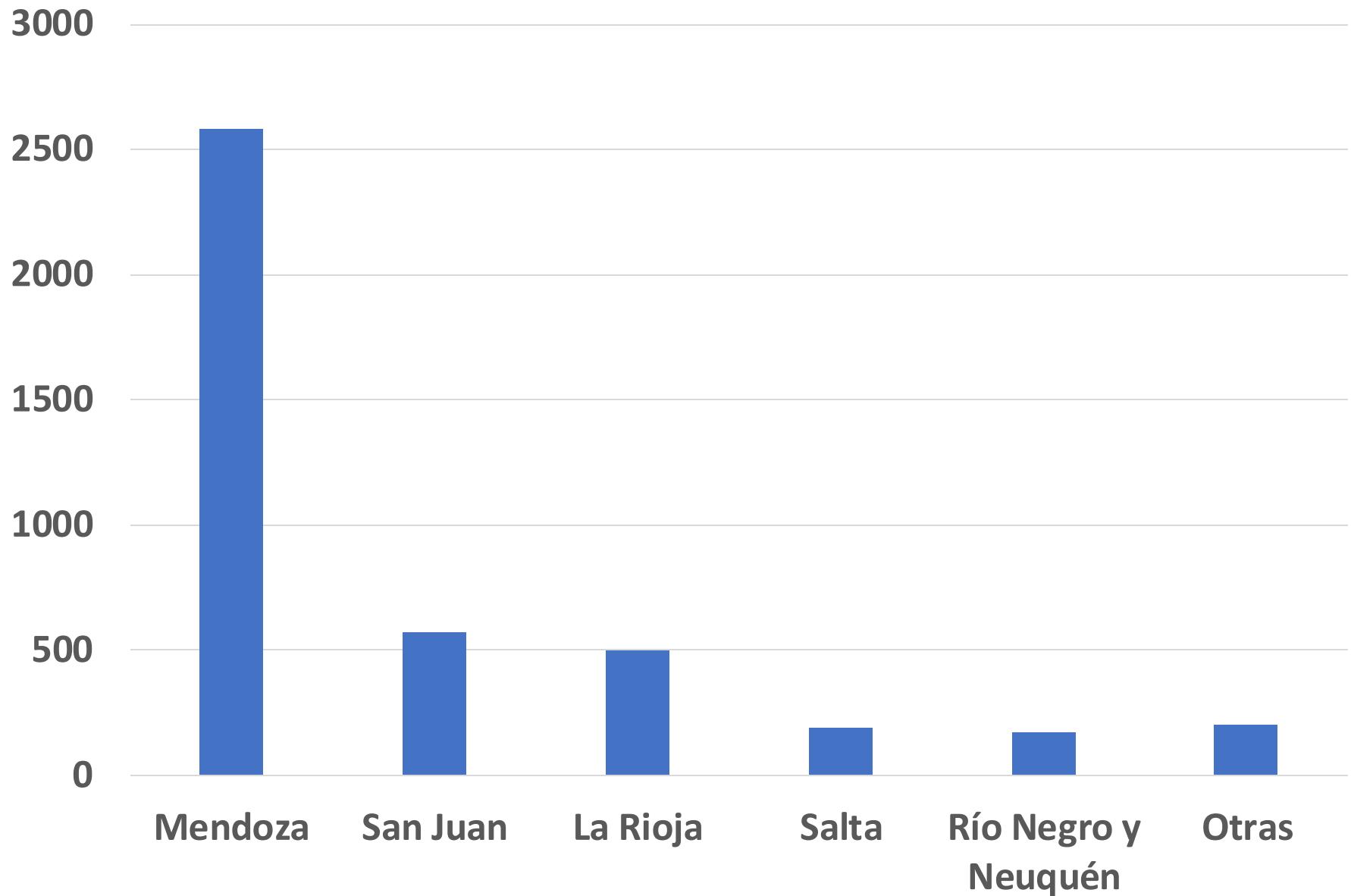


# PRODUCCIÓN DE ALMENDRAS CON CASCARA EN 2014 [TON]

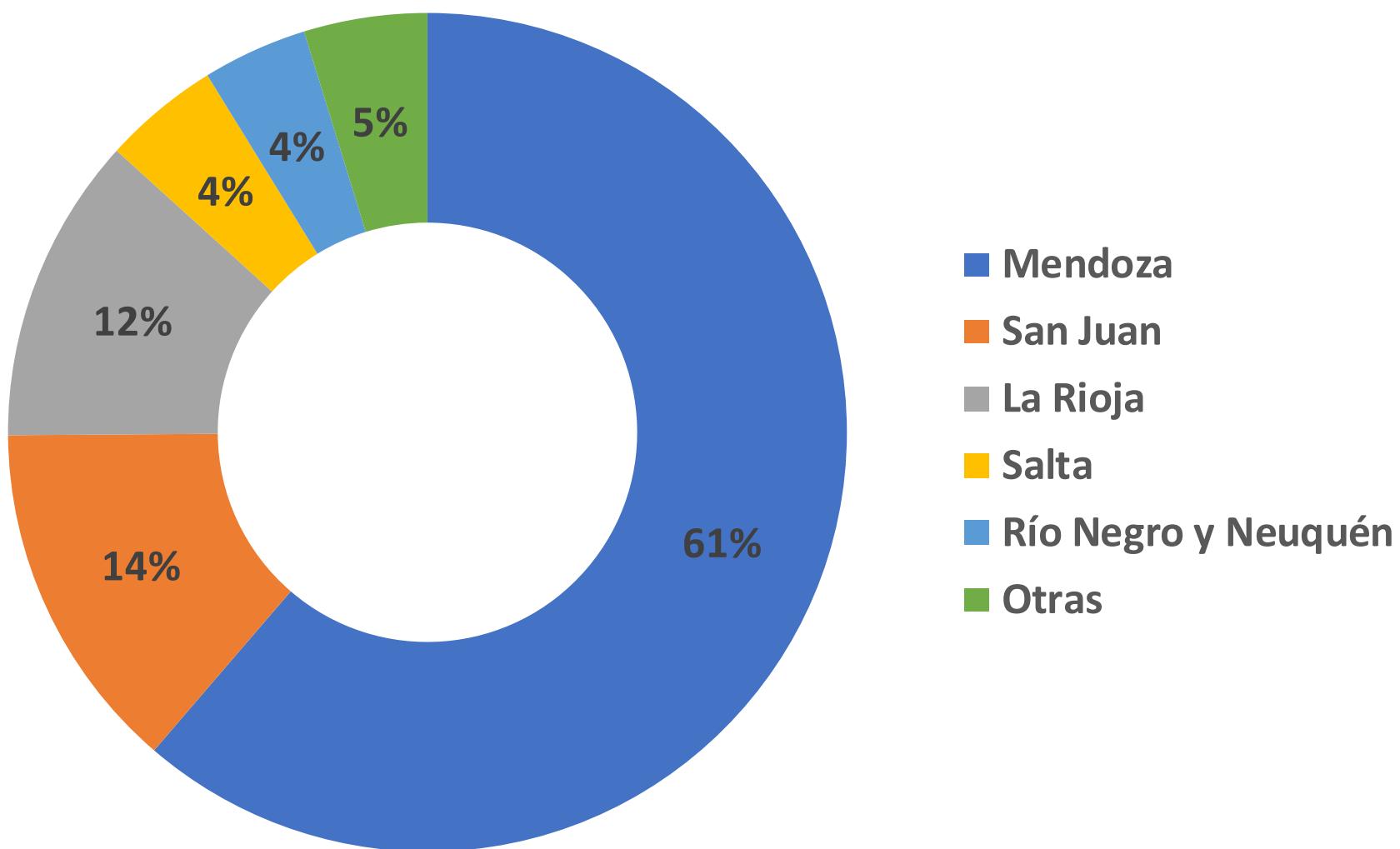




## Superficie cultivada 2015 [Ha]



## Superficie cultivada 2015 [Ha]







# *Proyecto de Desarrollo Tecnológico y Social*

*«Diseño e implementación de  
una estrategia para la  
clasificación óptica  
de almendras para  
pequeños productores»*

**Almendra**

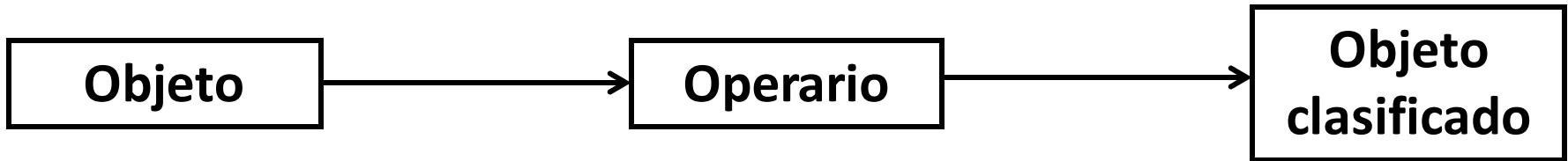
**Operario**

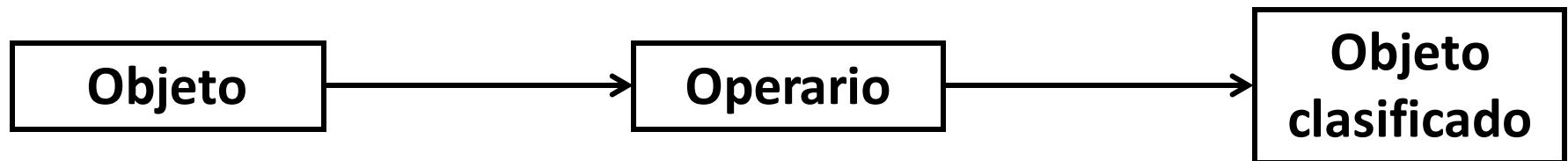
**Almendra  
clasificada**

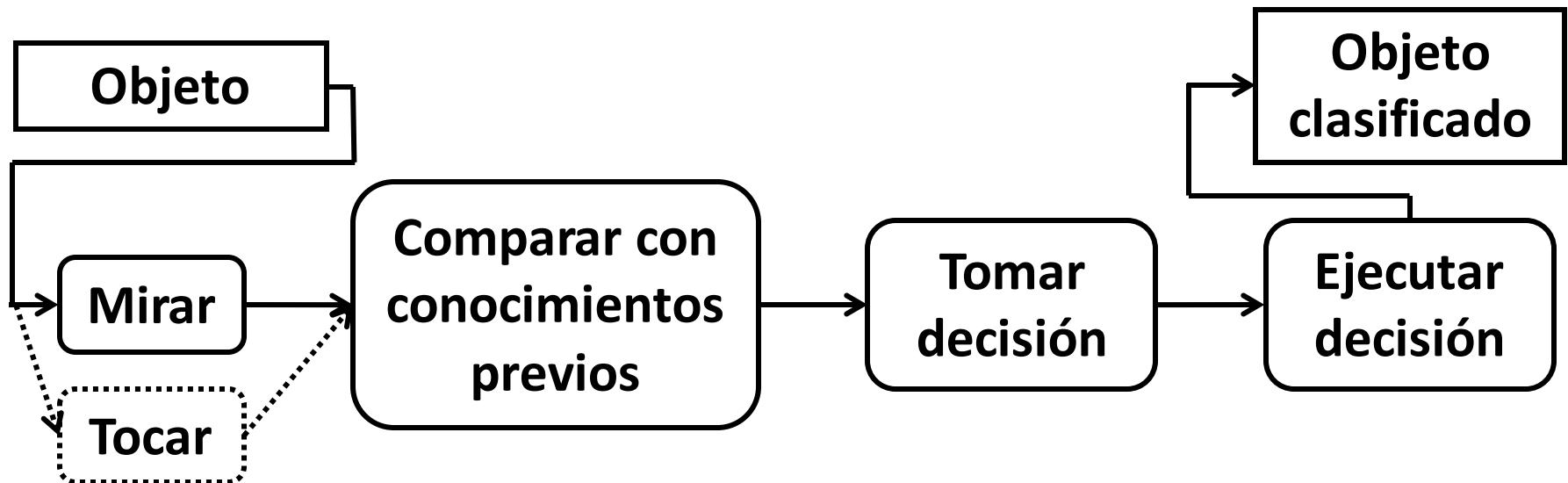


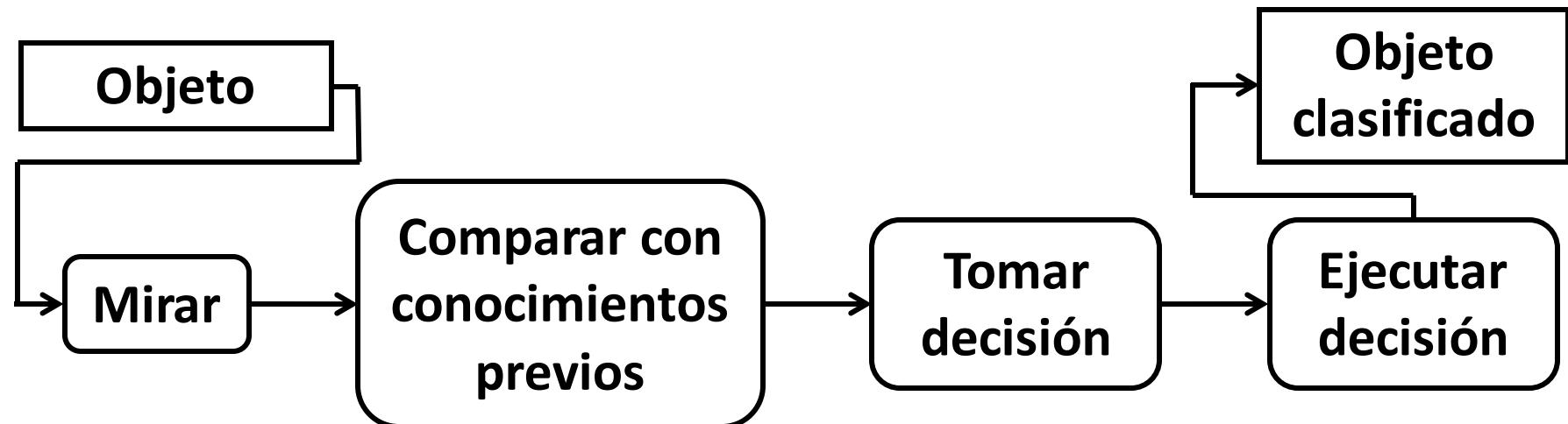
Almendra

*Objeto*



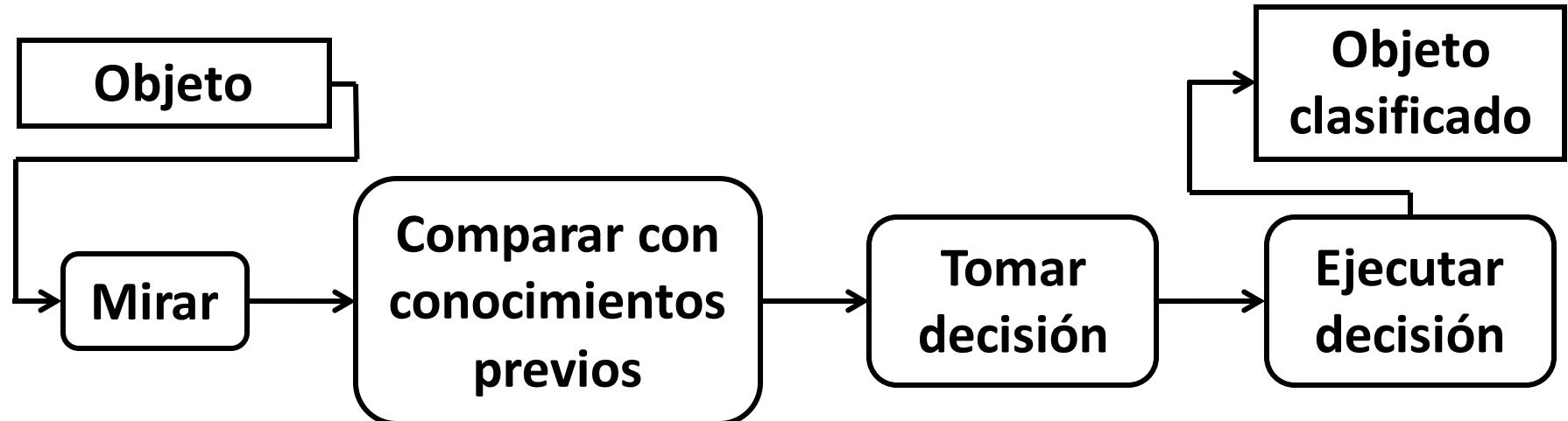






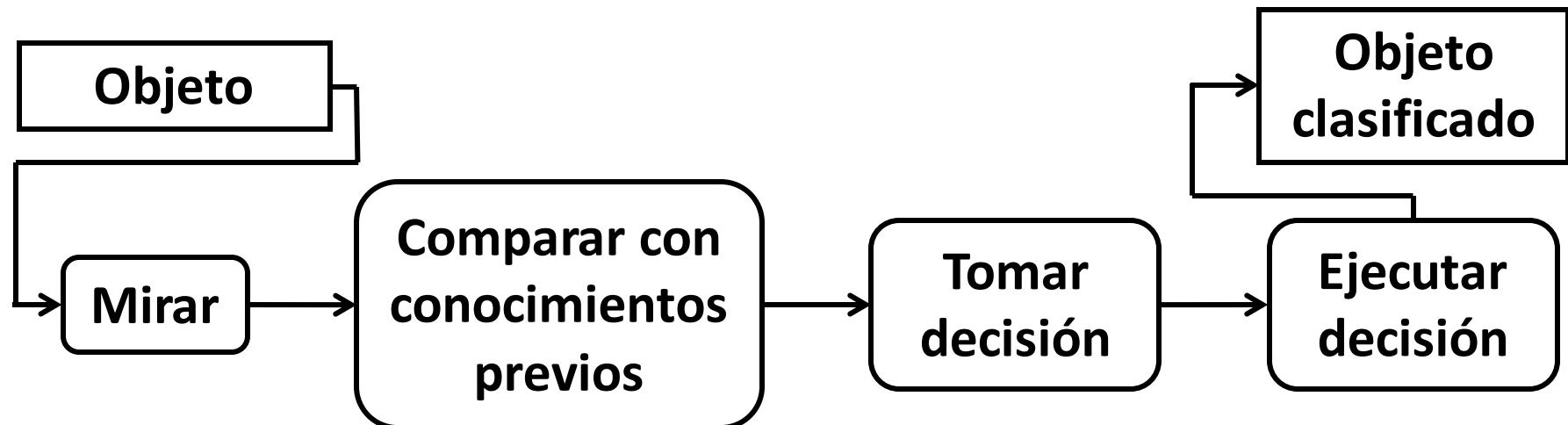
Estándares de  
calidad

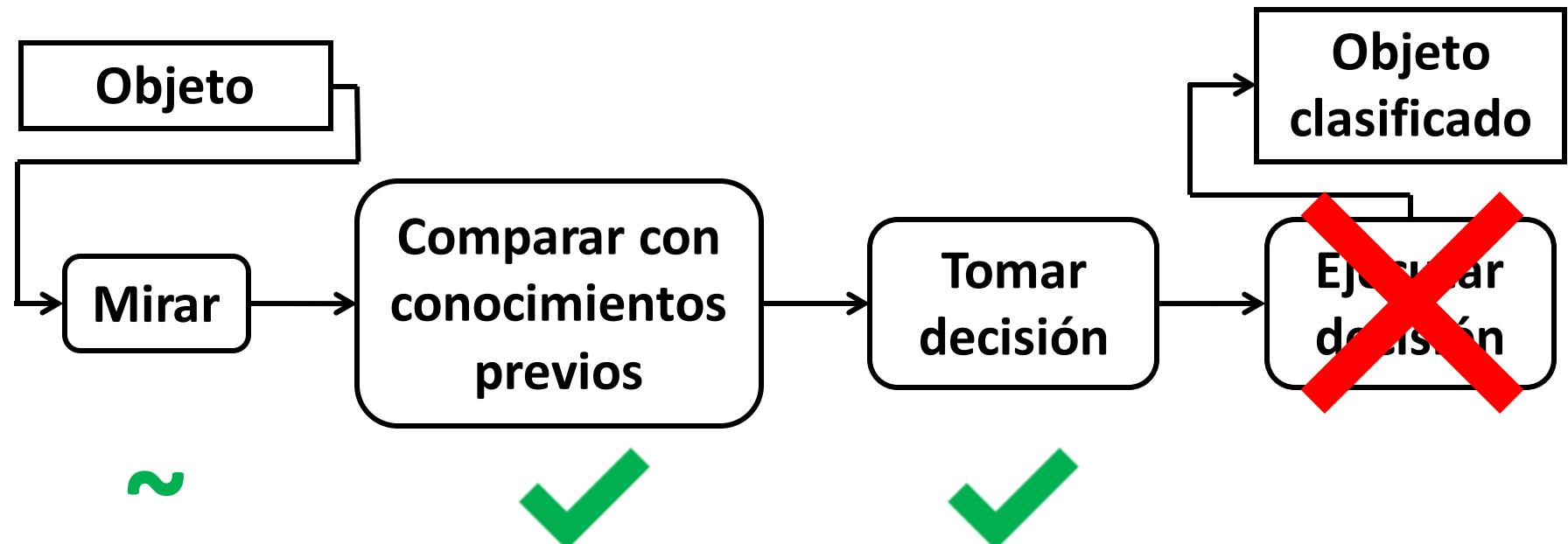




- . Mala
- . Buena
- . No es almendra
- . Sirve para helado

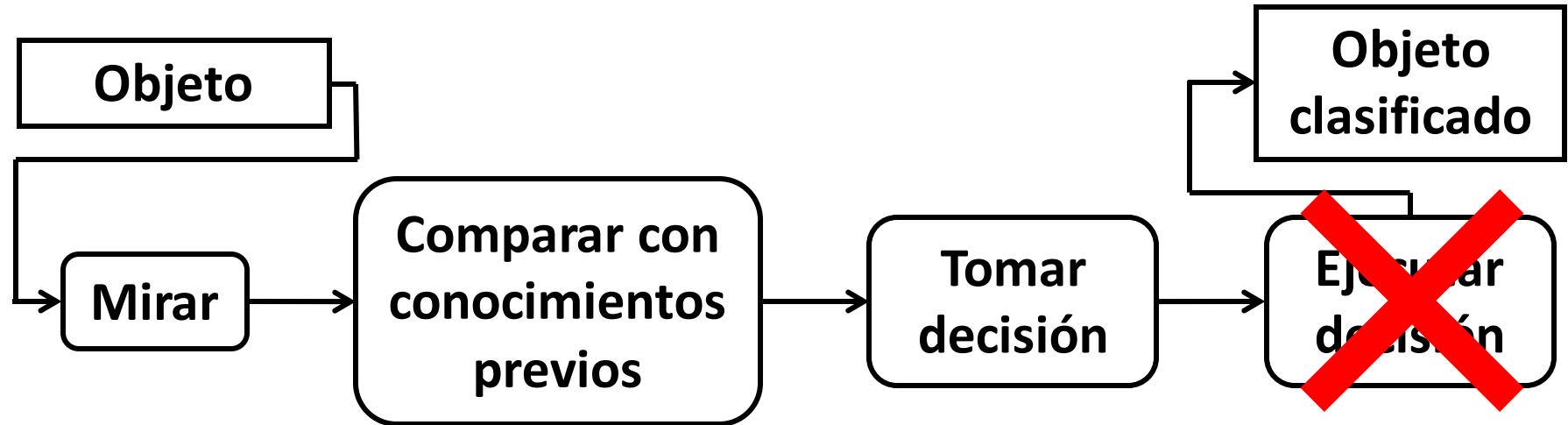


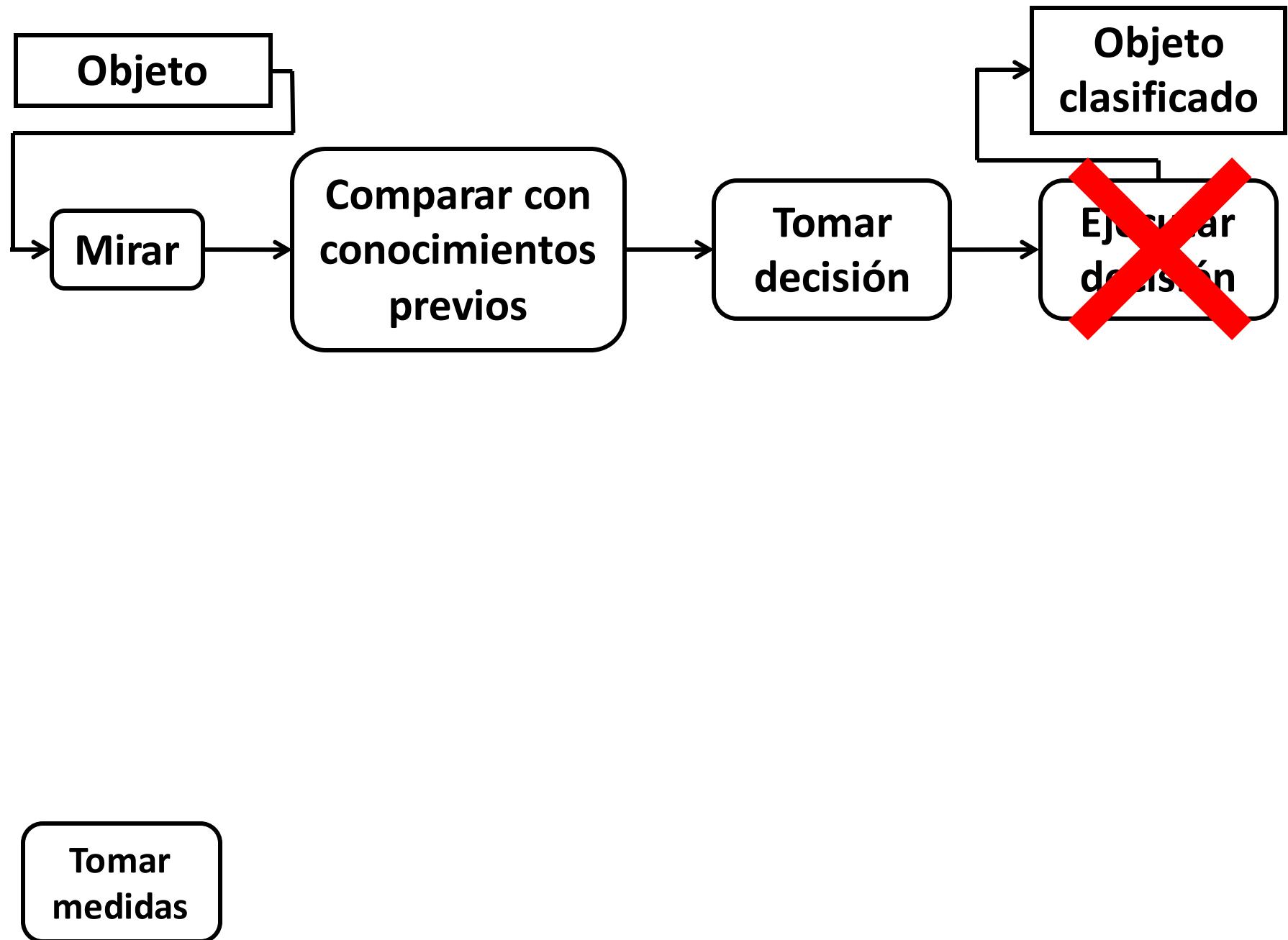


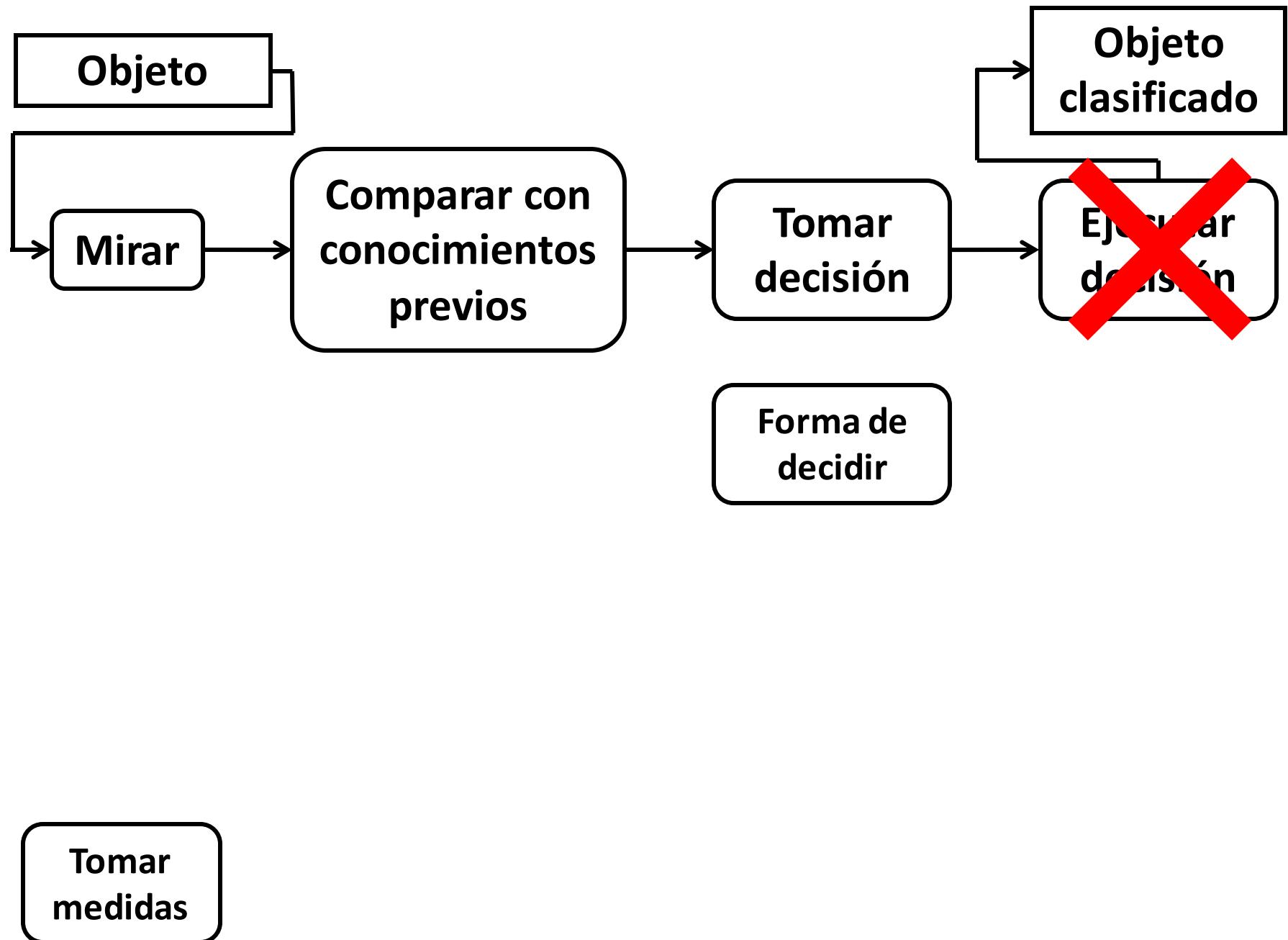


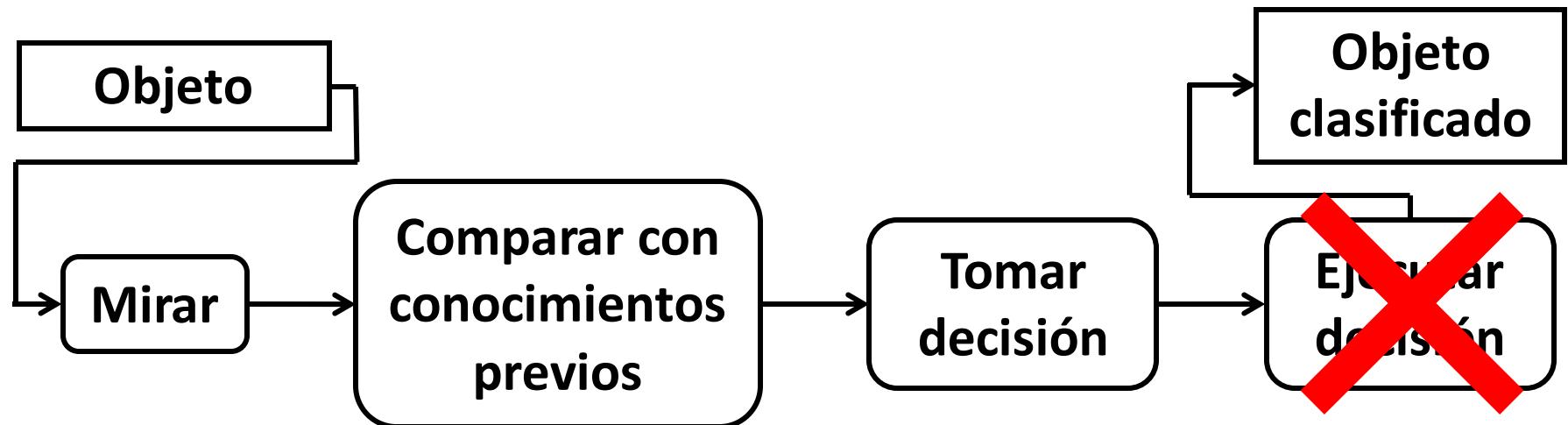
~







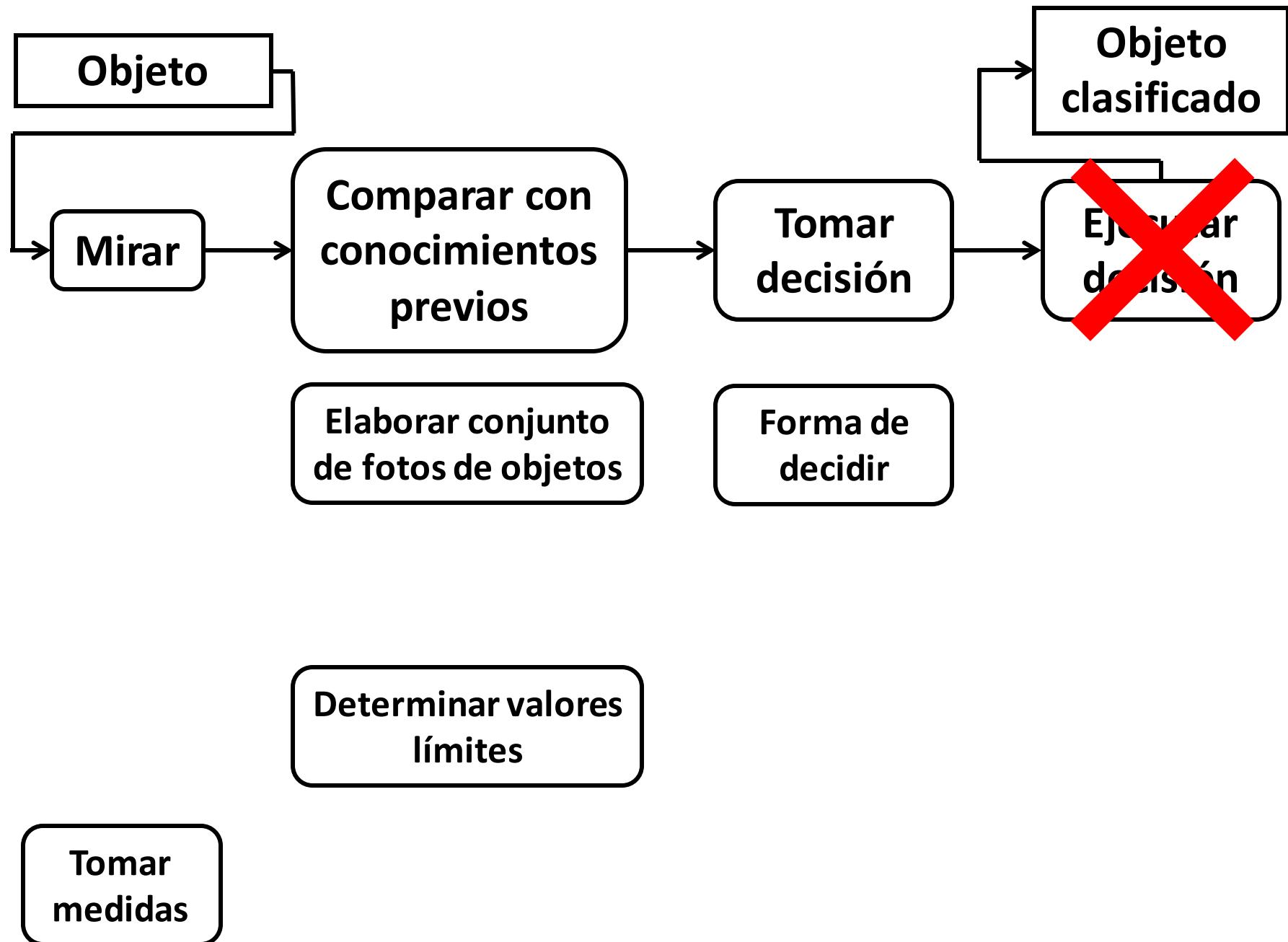


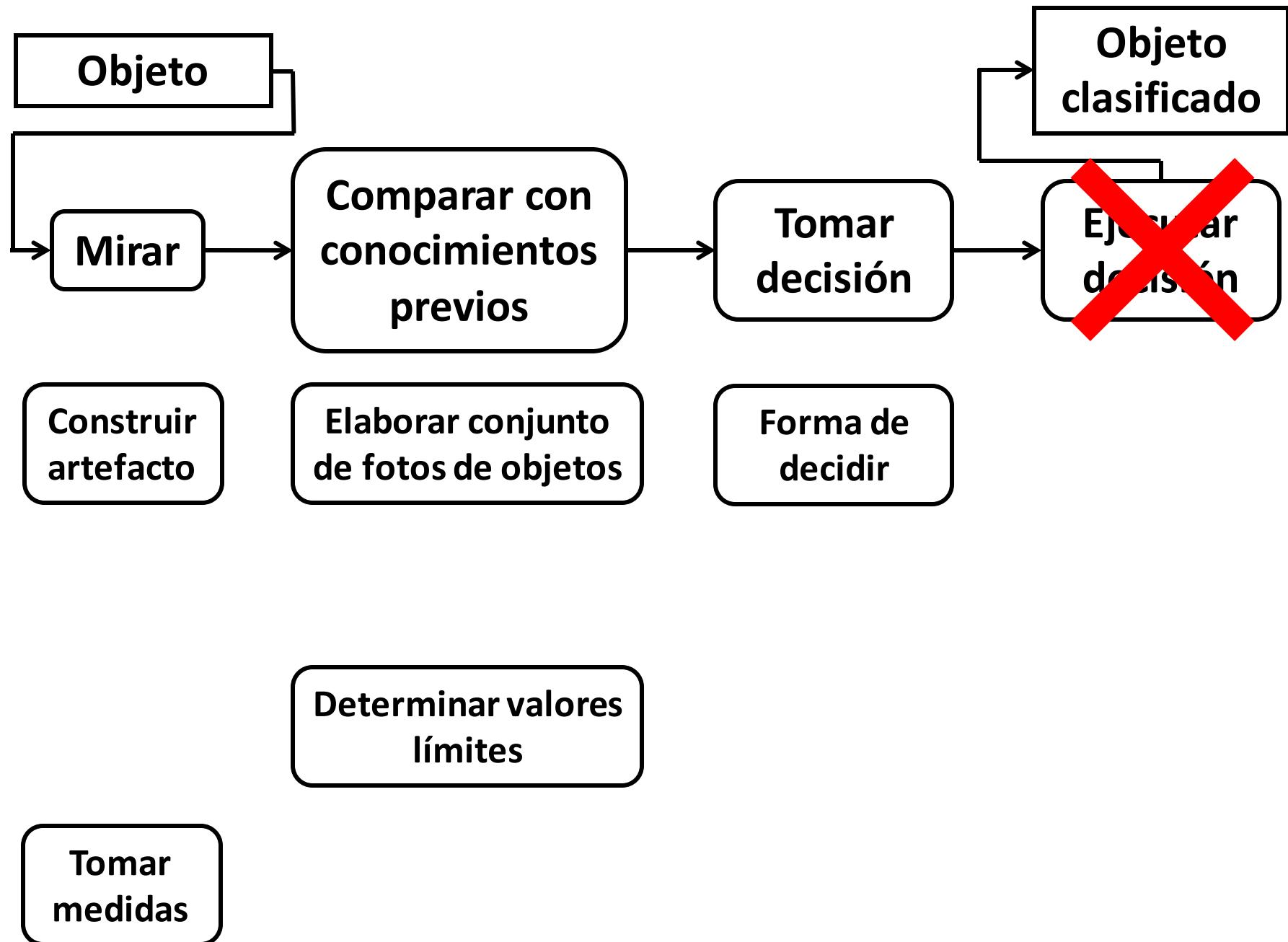


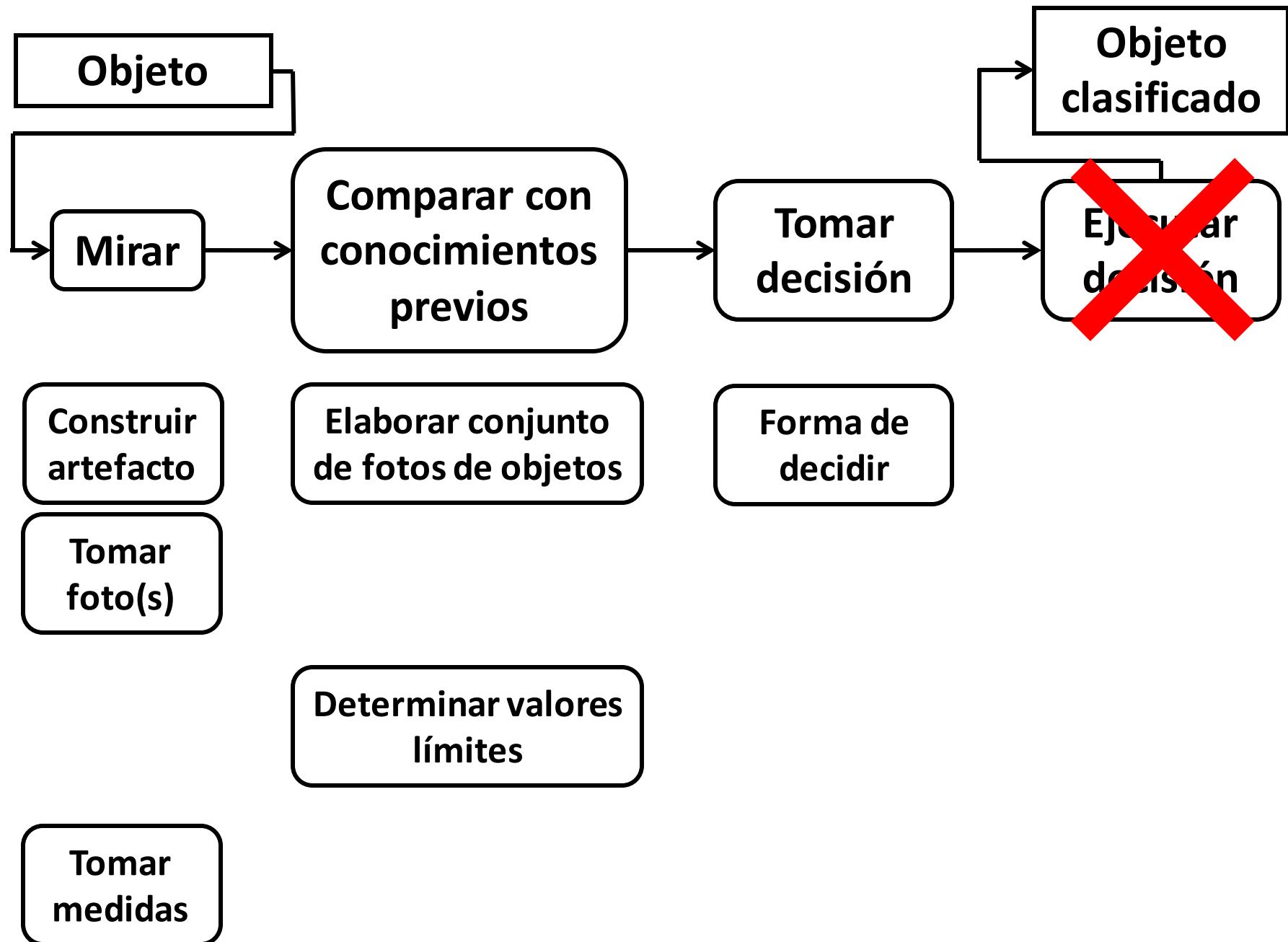
Forma de decidir

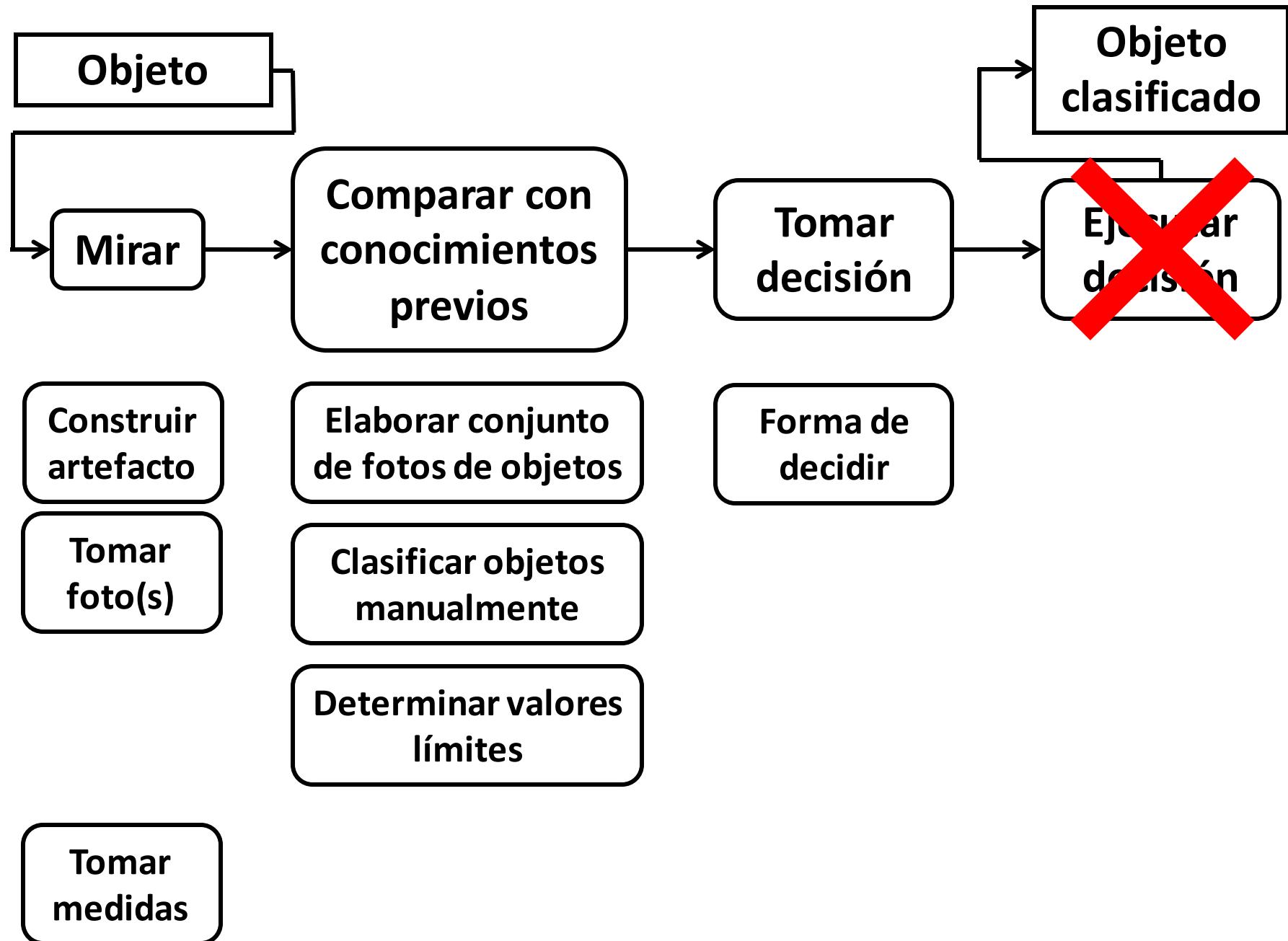
Determinar valores límites

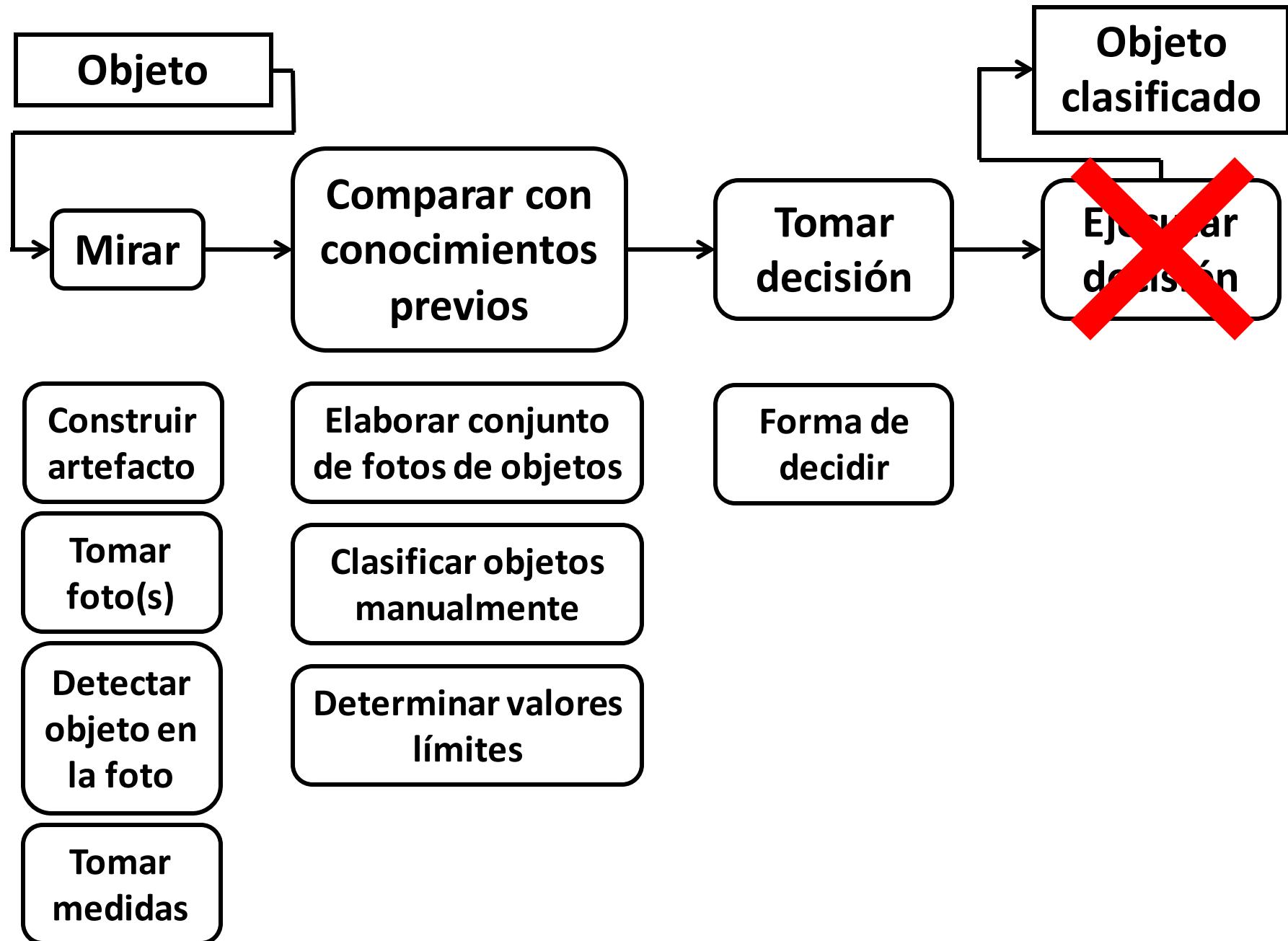
Tomar medidas



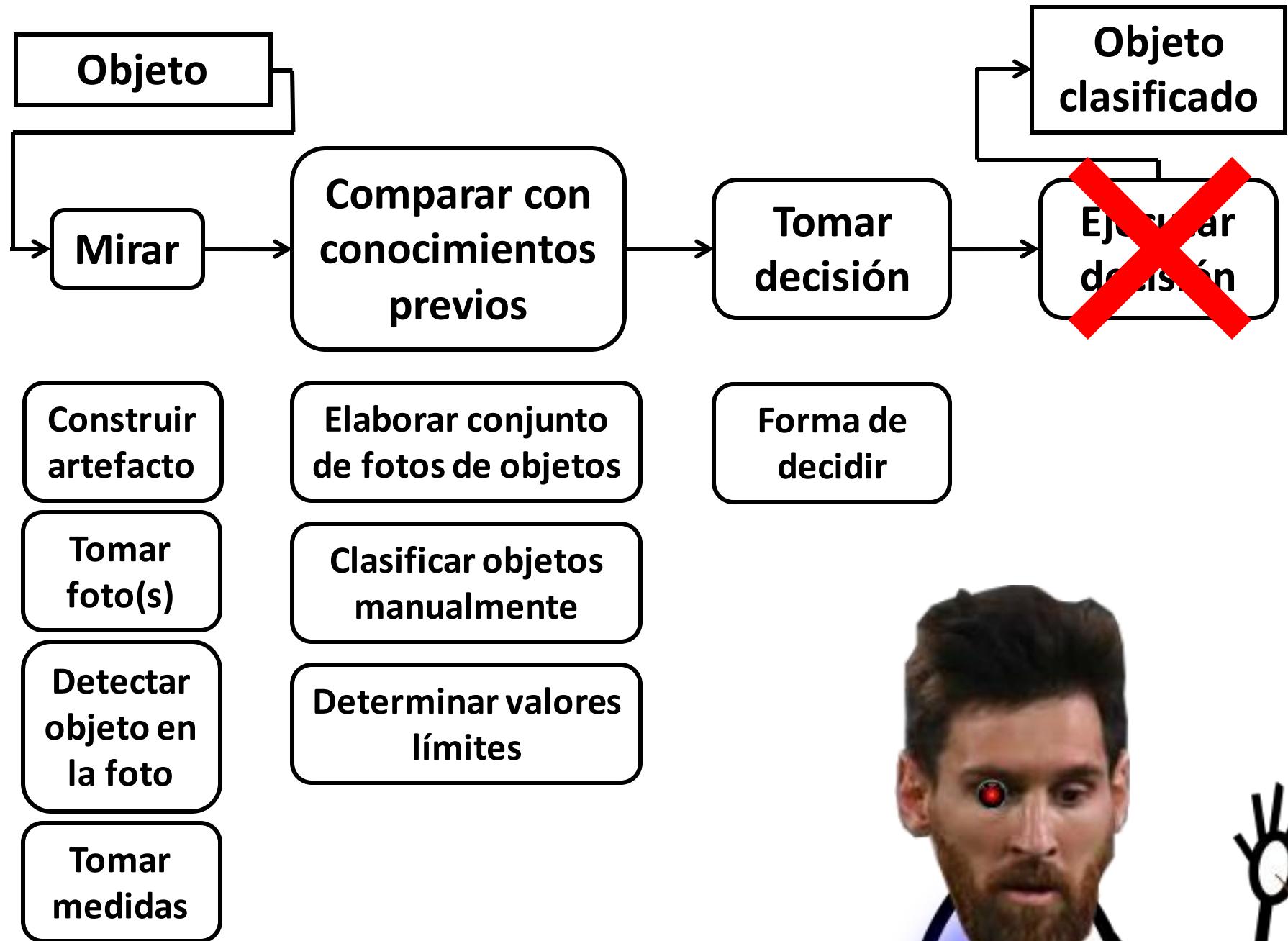


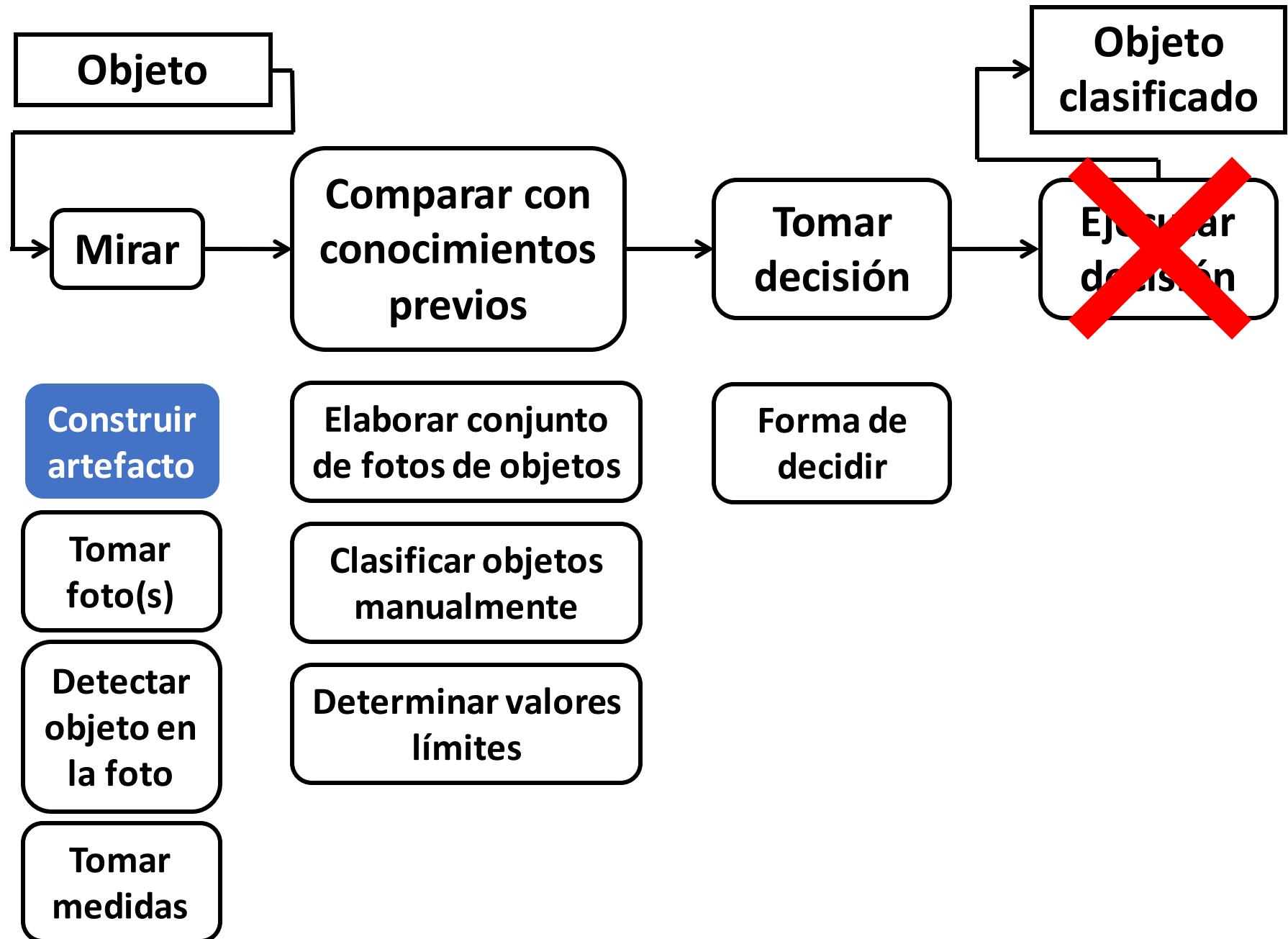






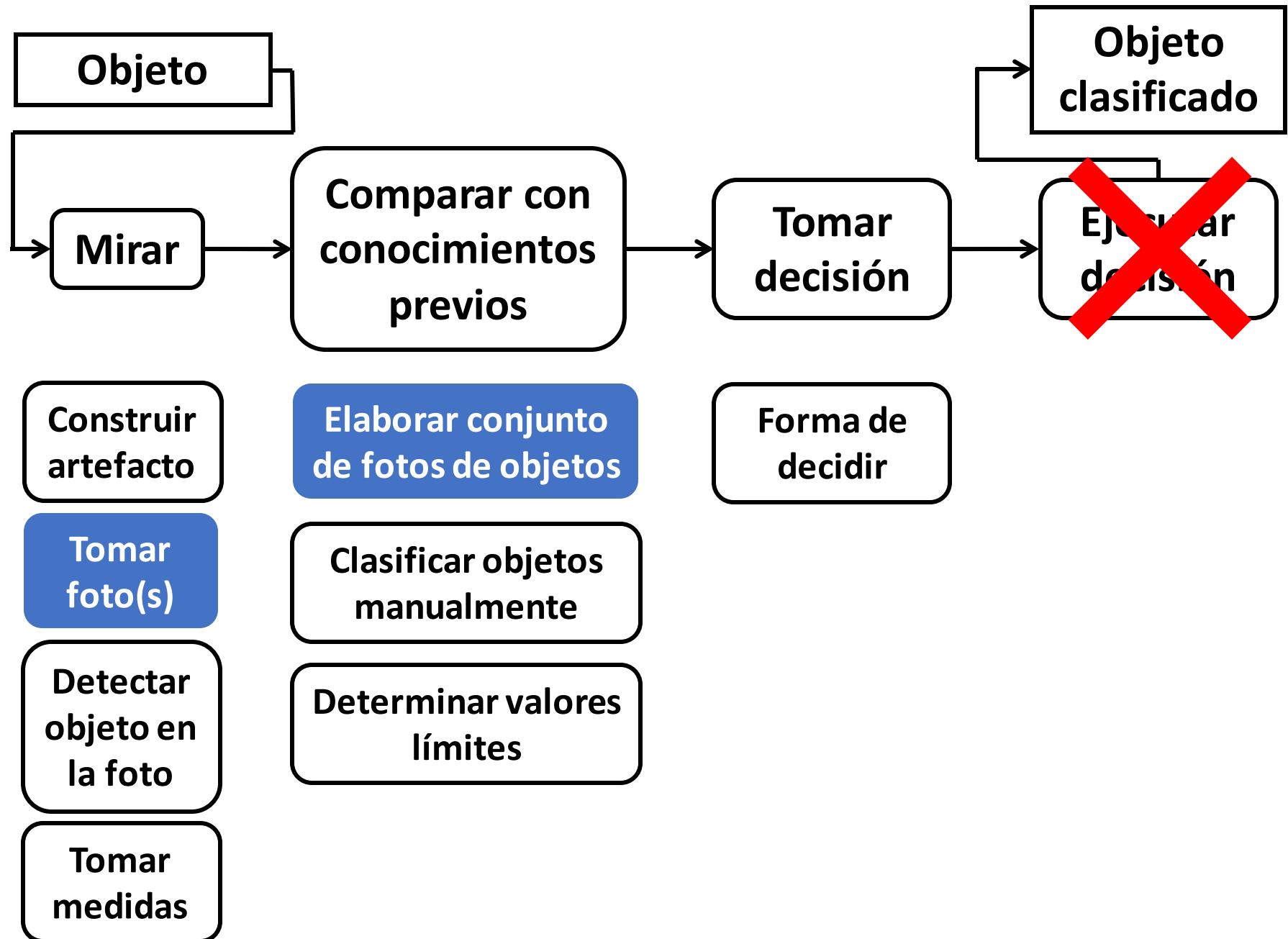






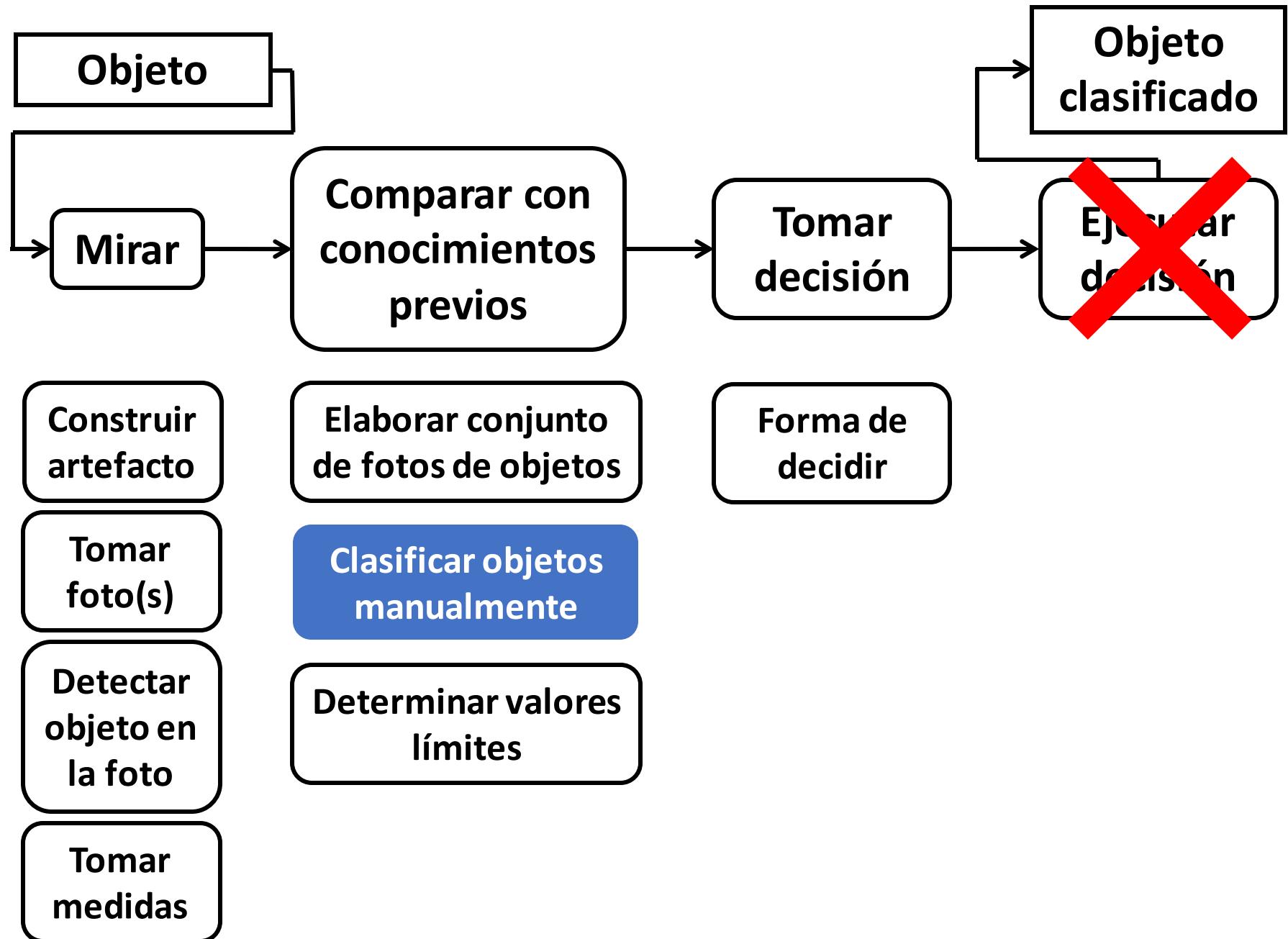




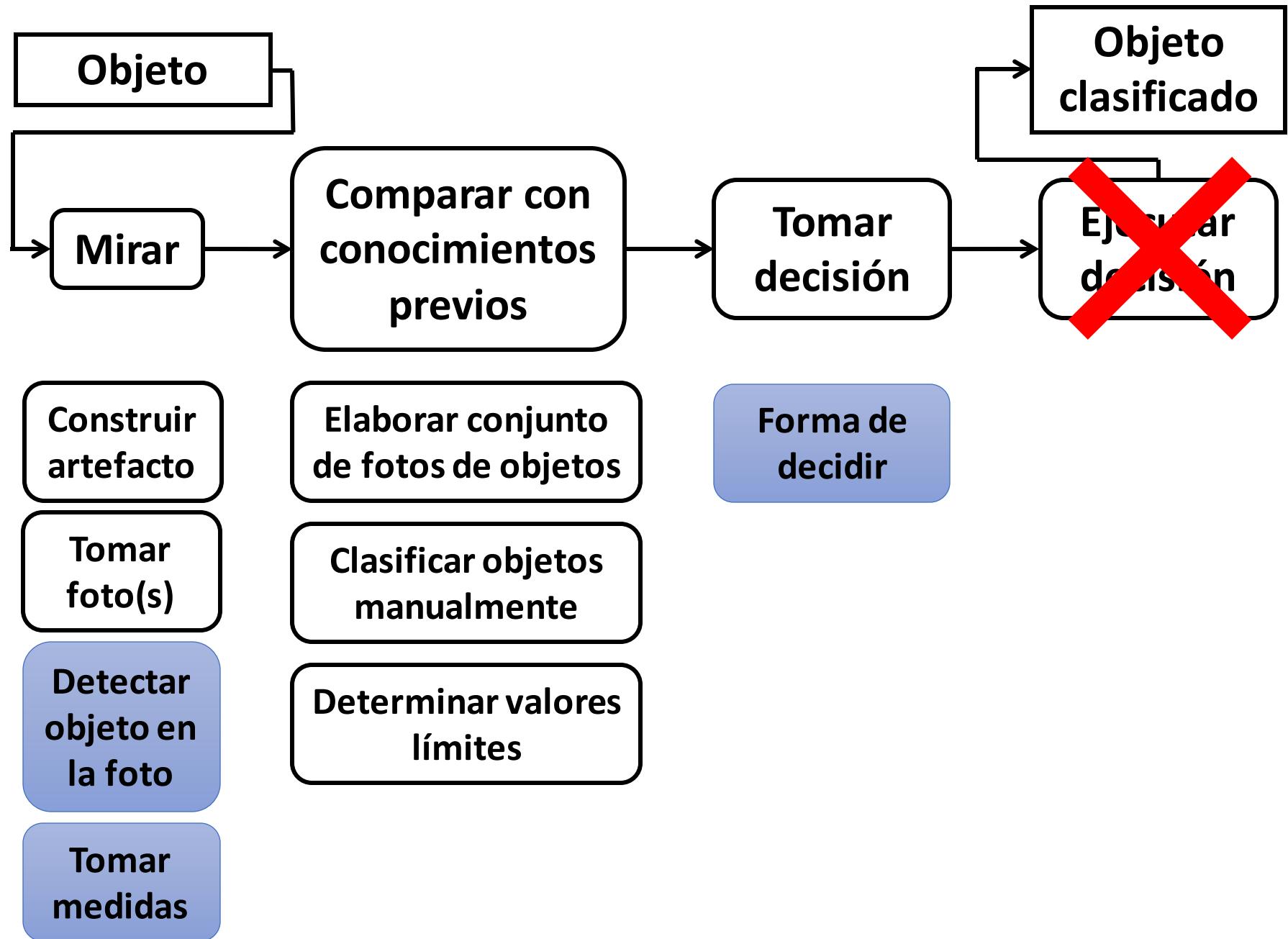












```
130 end % methods protected
131
132
133
134 %% Métodos privados
135 methods(Access = private)
136
137
138 function [angulo_medio] = clasificarImagen(obj, imagen, mascara)
139     %CLASIFICARIMAGEN
140     % Uso: [desviacion] = clasificarImagen(obj, imagen, mascara)
141     % *angulo_medio*: Media del color (canal H) en el objeto.
142     % *imagen*: Imagen RGB.
143     % *mascara*: Imagen binaria. Fondo negro, objeto en blanco.
144
145
146     % Validación de entradas
147     % ToDo
148     %- La mascara es bidimensional y lógica
149     validateattributes(mascara, {'logical'}, {'nonempty', 'ndims', 2}, ...
150         'clasificarImagen', 'i_mascara', 2);
151
152
153     % Erosión de la máscara, porque en los bordes no hay
154     % información de color confiable.
155     SE = strel('disk', obj.p.radio_erosion.valor);
156     mascara = imerode(mascara, SE);
157
158
159     % Conversión a HSV
160     hsv = rgb2hsv(imagen);
161     h = hsv(:, :, 1);
162
163     % Aplicación de máscara y normalizado a 360 grados
164     h = 360 * h(mascara);
165
166     % Conversión a vector
167     h = h(:);
168
169
170     % ESTADÍSTICA DIRECCIONAL o ESTADÍSTICA CIRCULAR
171     % Conversión a coordenadas cartesianas, desde polares. Cada ángulo
172     % representa un vector de longitud unitaria. Las componentes, entonces, son
173     % el coseno y el seno del ángulo.
174     [cartesianas_cos, cartesianas_sin] = pol2cart(deg2rad(h), ones(size(h)));
175
176     % Se construye un vector R formado por la suma de cada uno de los ángulos
177     % iniciales. El ángulo de R es el ángulo medio de los vectores, mientras
```

gui

Etapas del algoritmo

Vistas

Etapa

Frente

Dorso

Segmentador bobo

altura

extent

relación de aspecto de elipse

**área de raspaduras**

solidez

media de color

medias a y b CIELab

desviación estándar de color

Parámetros de la etapa

h\_min 25.4118

h\_max 104.471

s\_min 0

s\_max 0.862745

v\_min 0.184314

v\_max 1

umbral\_max\_mm2 7.06858

factor\_escala 0.0384615

radio\_erosion\_inicial 2

radio\_apertura 7

Clase real Clase estimada

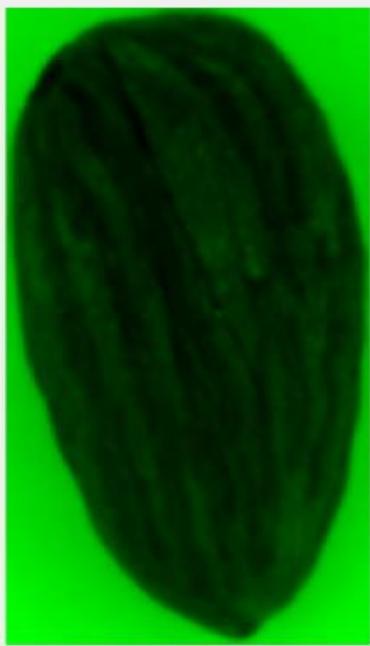
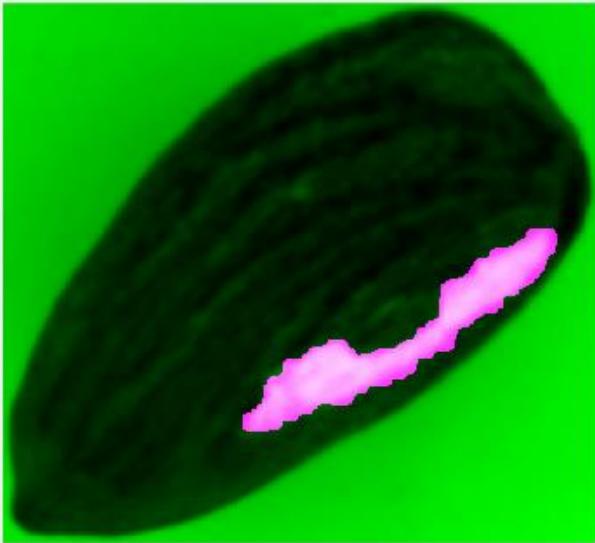
**Mala Mala**

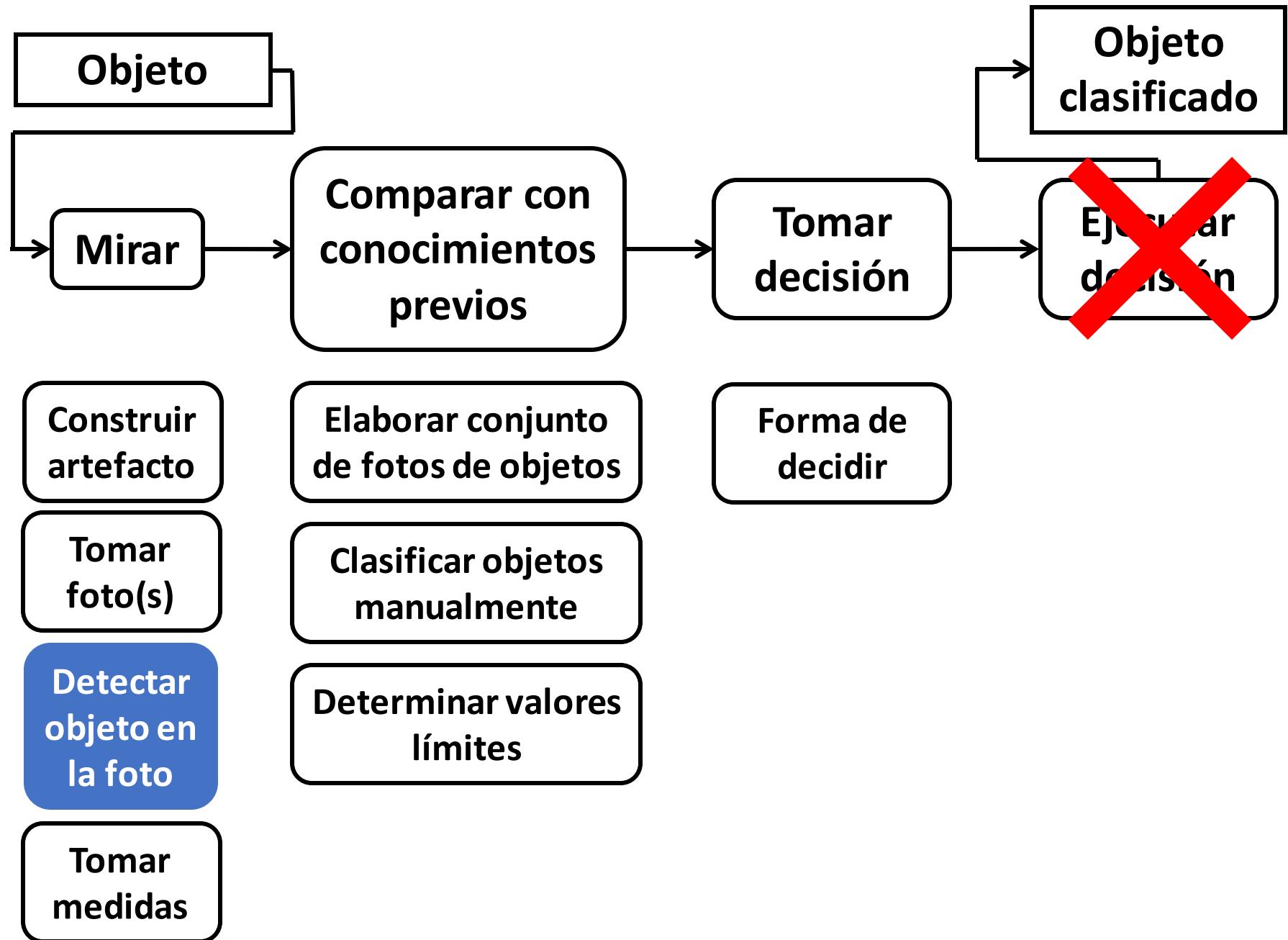
Clase Primera según clasificador altura  
523.000000

Clase Primera según clasificador extent  
0.769446

Clase Primera según clasificador relación de aspecto de elipse  
0.531104

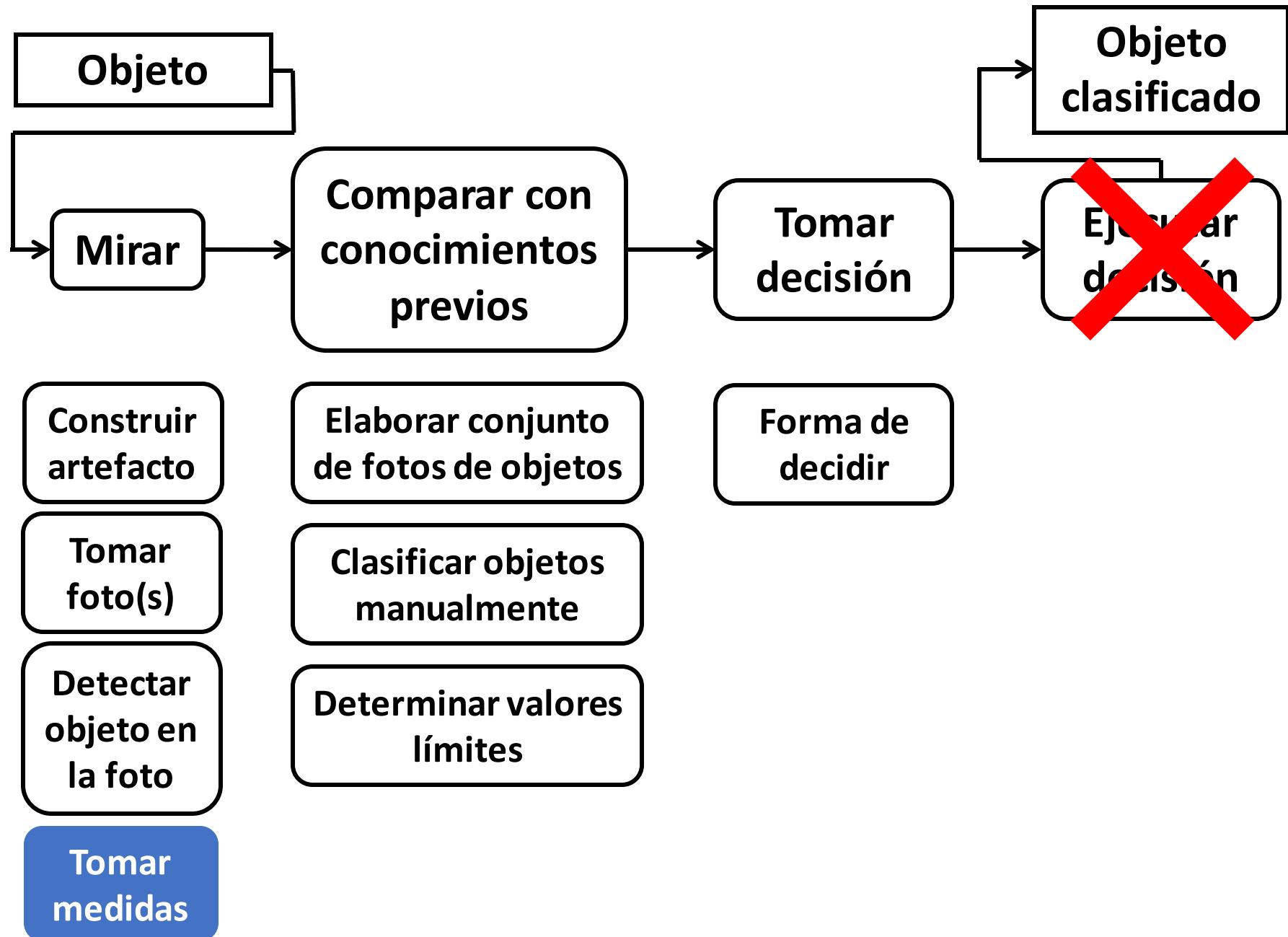
Clase Mala según clasificador área de raspaduras  
13.547337

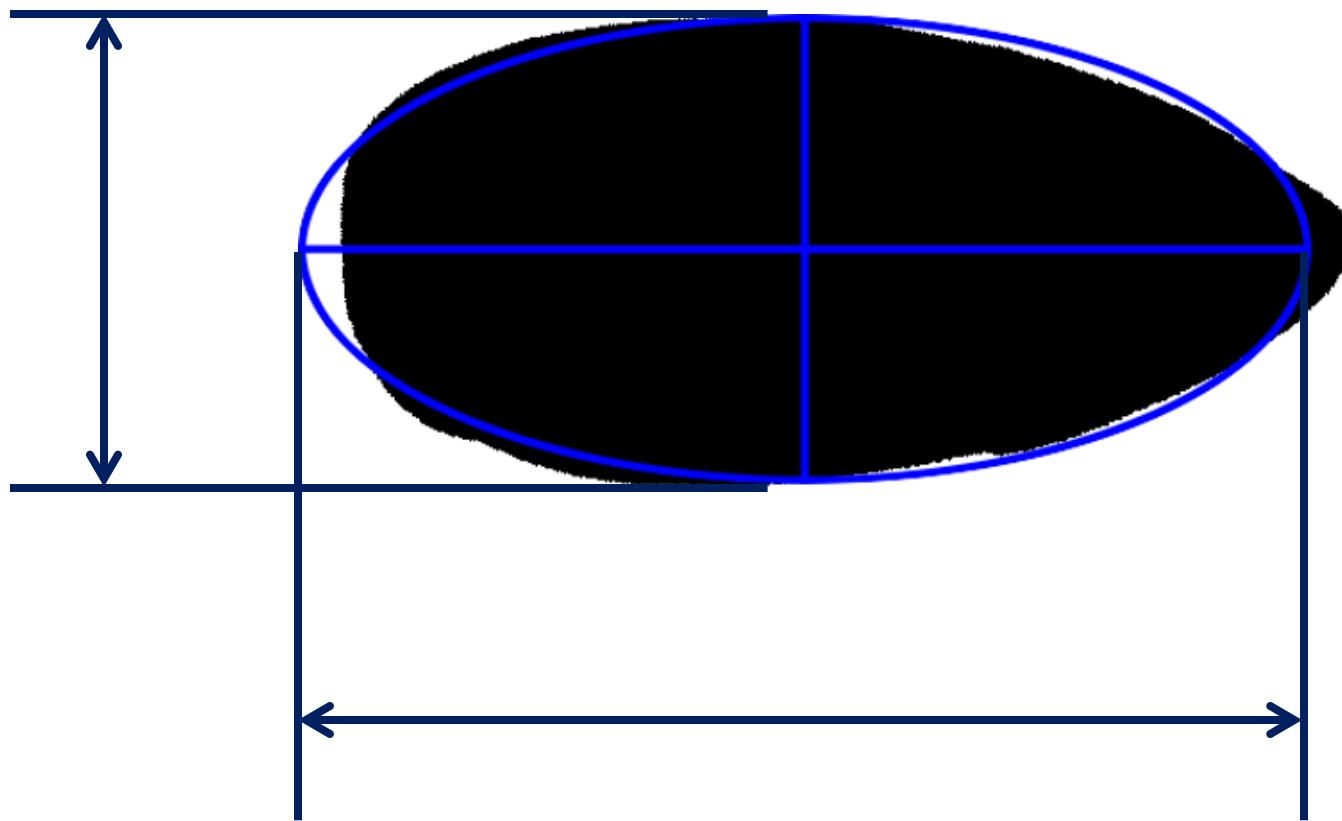


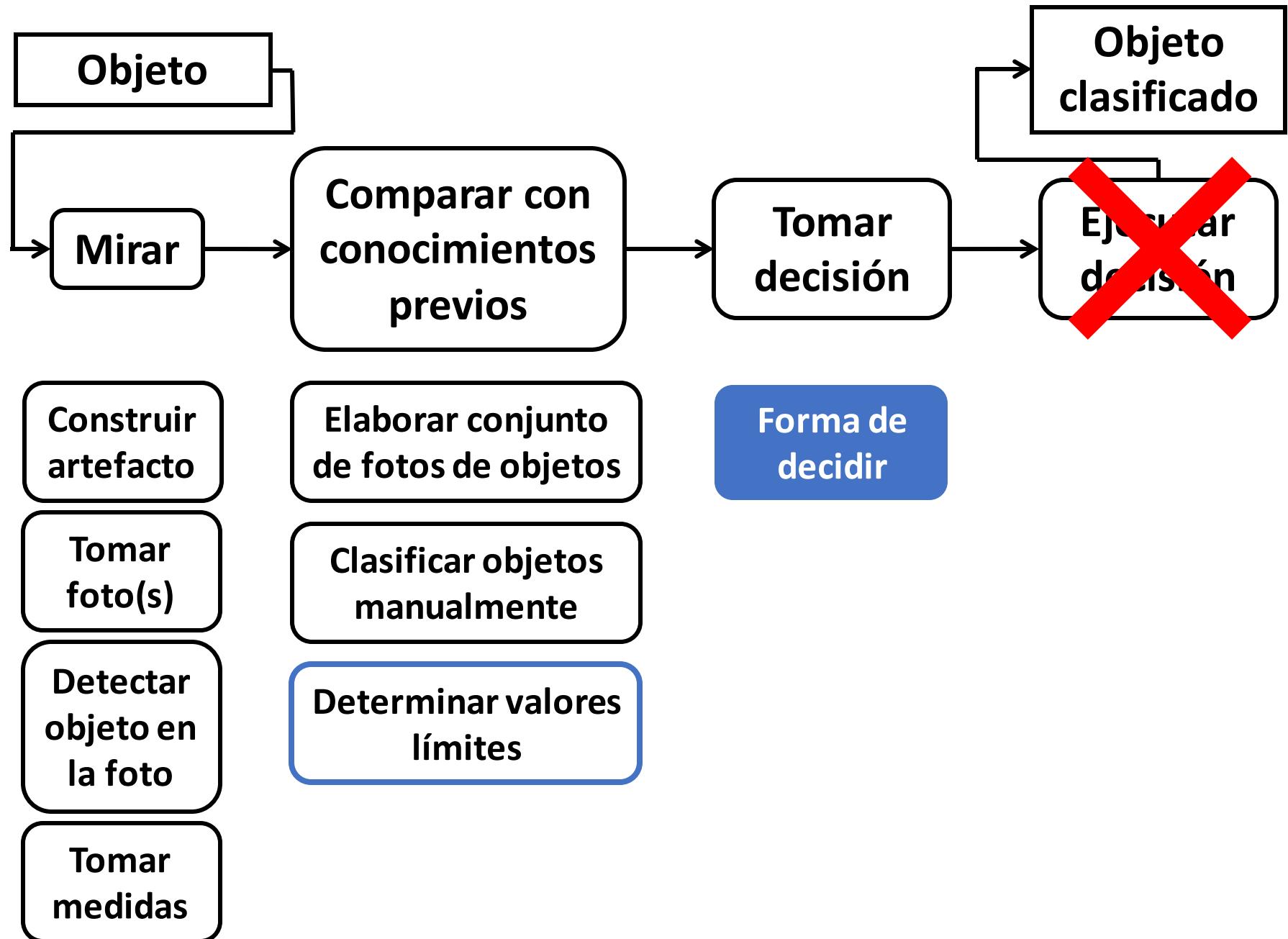


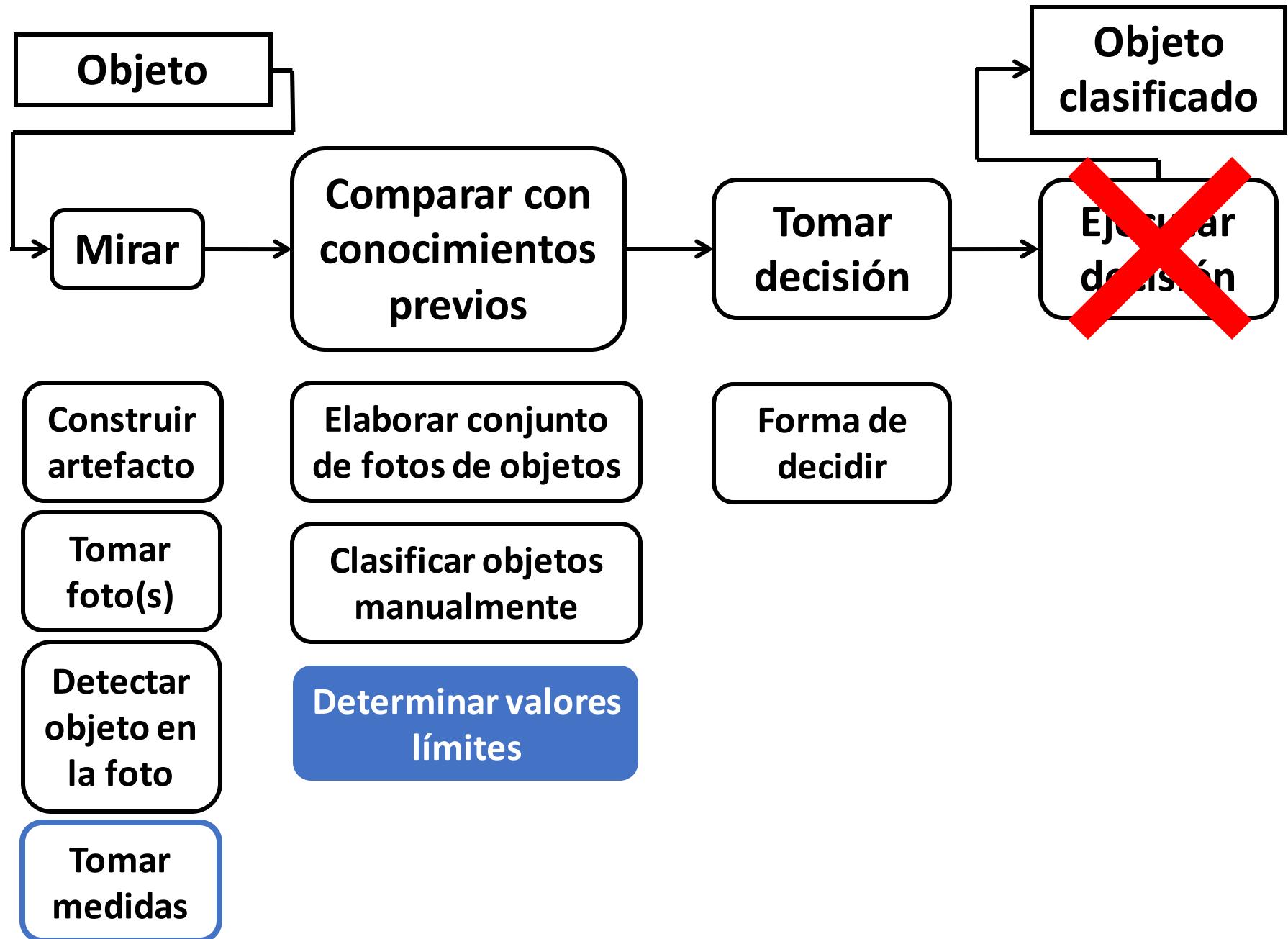












# Desarrollo de la máquina

- Cosas a medir
- Forma de decidir (clasificador)
- Valores para distinguir
- Conjunto de fotos. Clasificación manual
- Artefacto
- Comparar con realidad
- Comparar varias formas de hacer las cosas



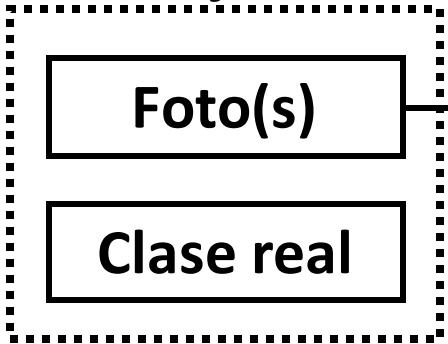




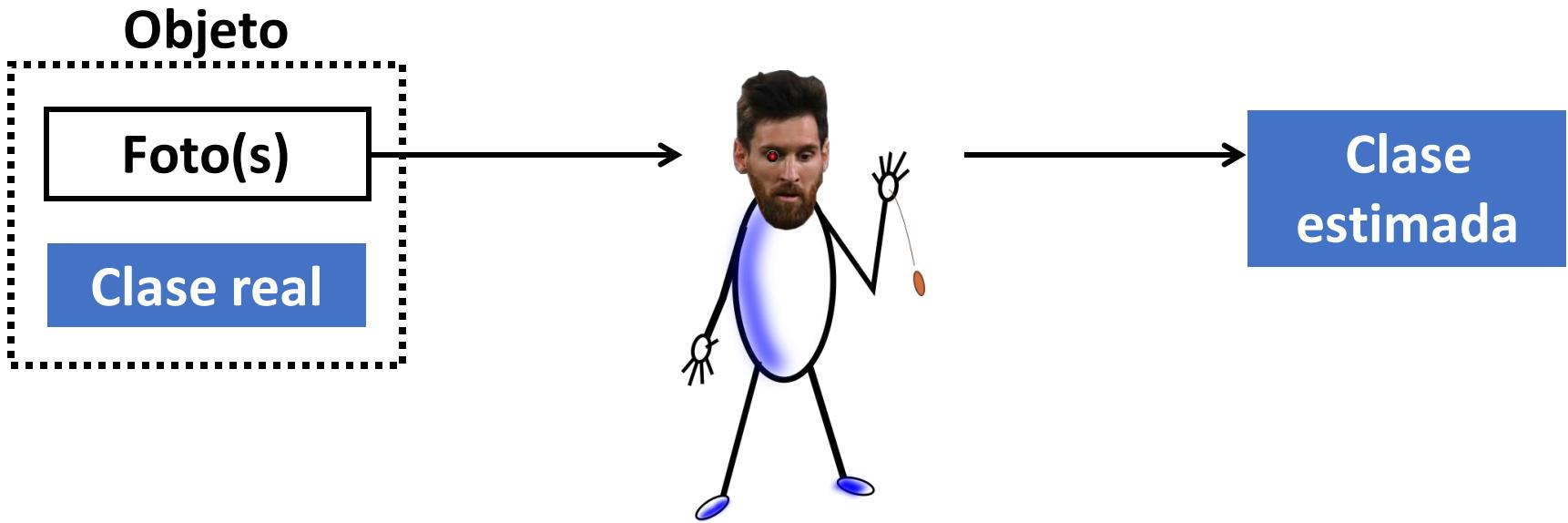
**Entrenamiento /  
Ajuste**

**Evaluación**

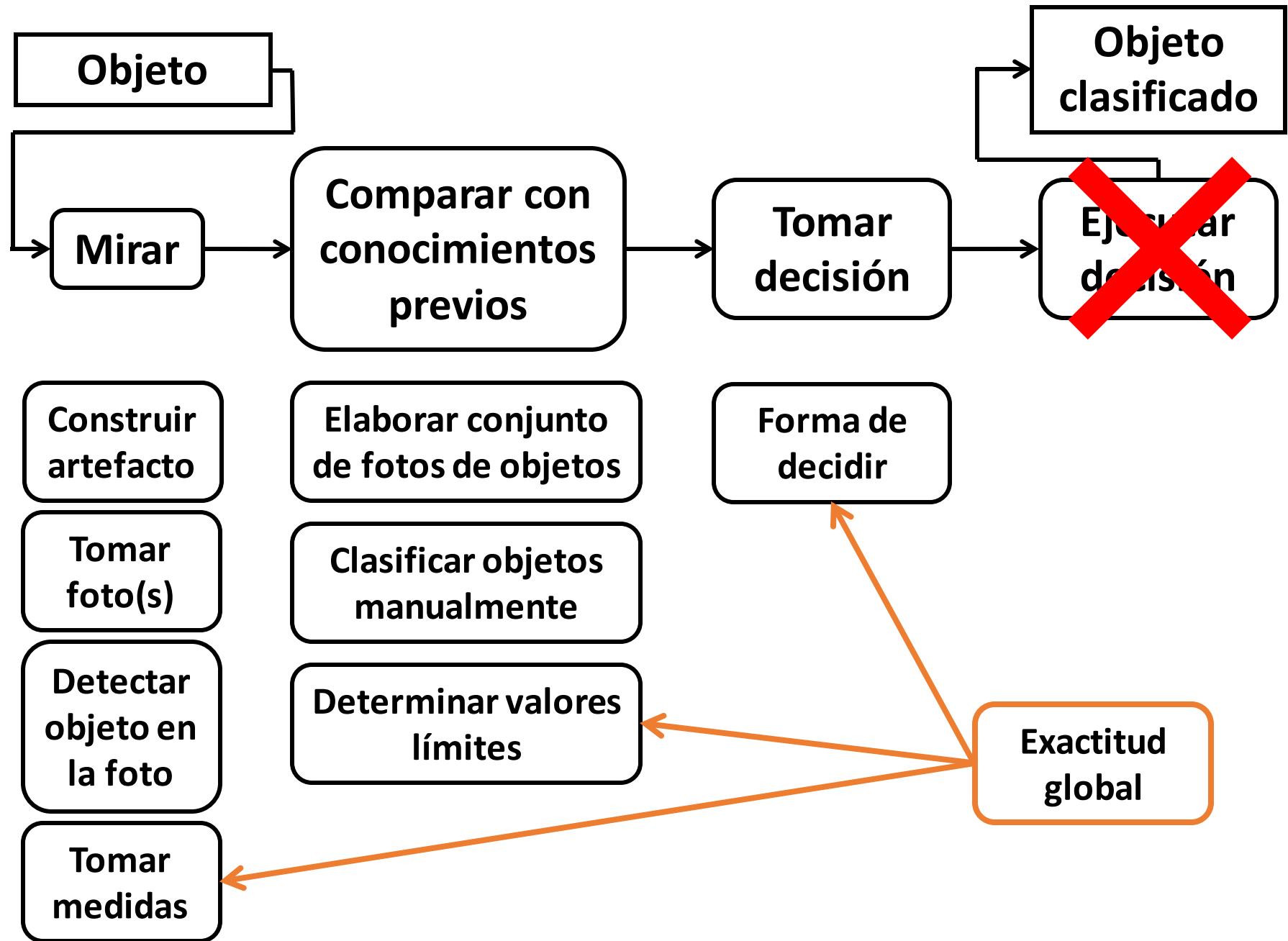
# Objeto

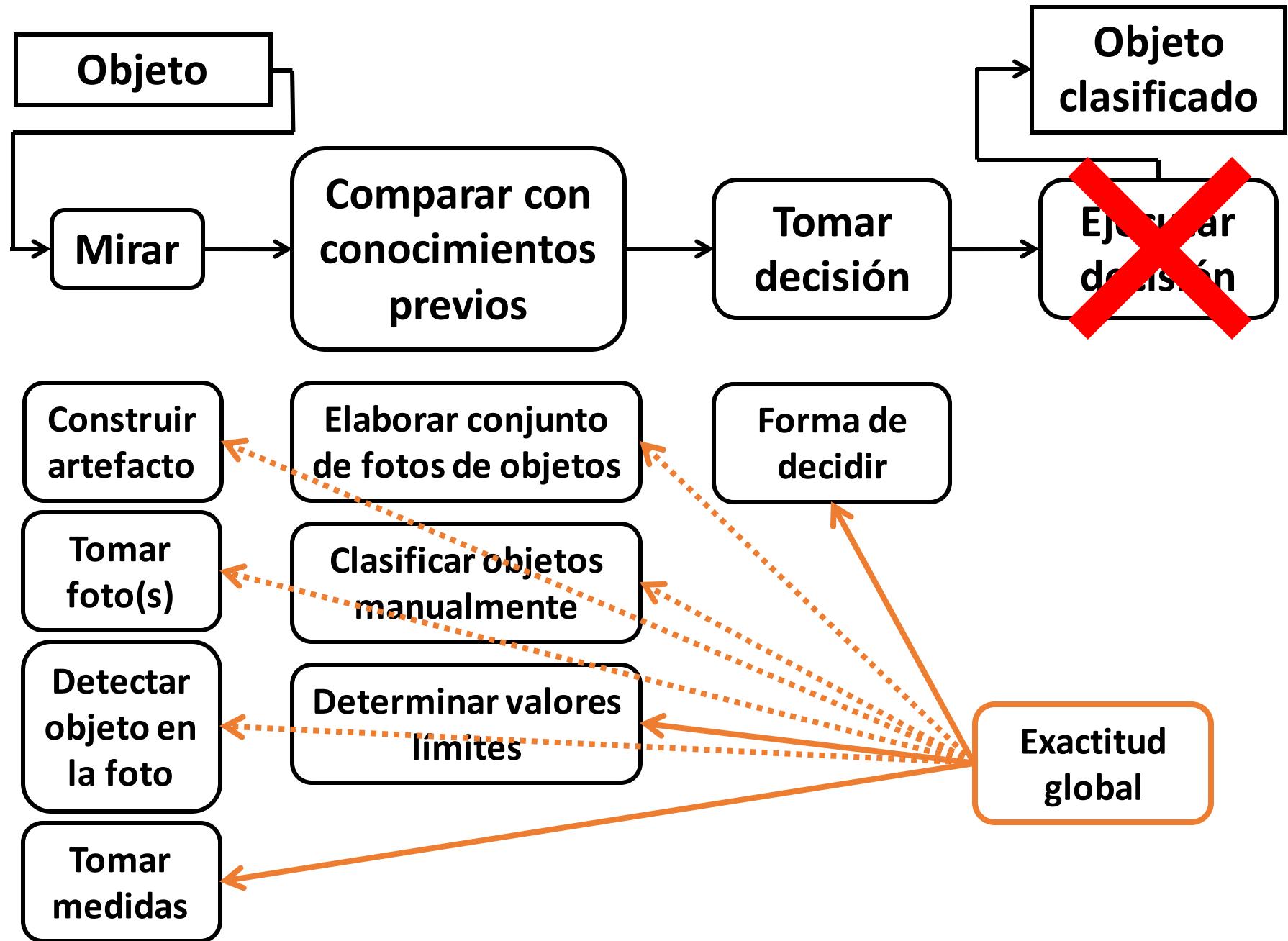


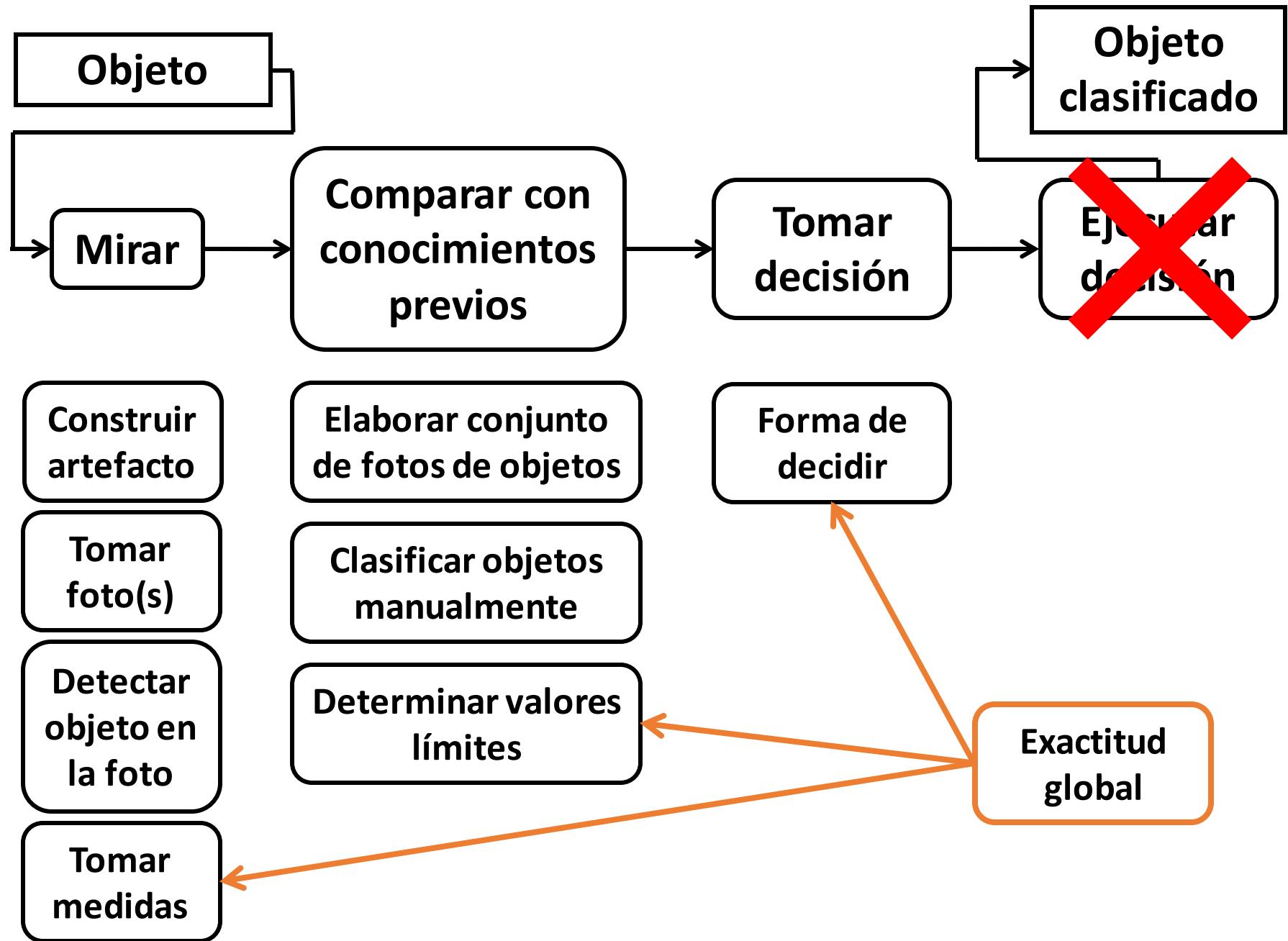
Clase  
estimada



Exactitud global = objetos clasificados correctamente  
total de objetos



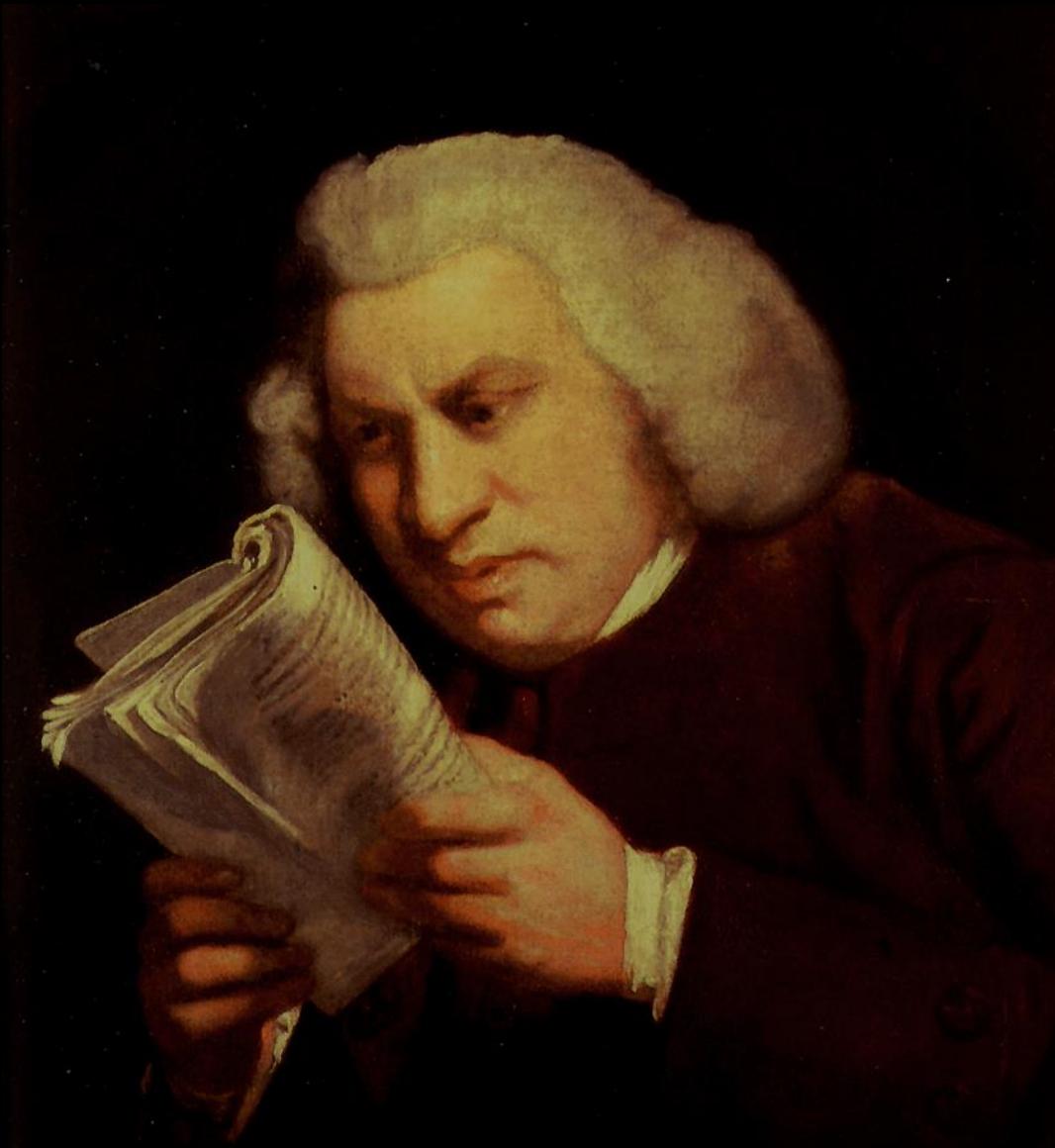


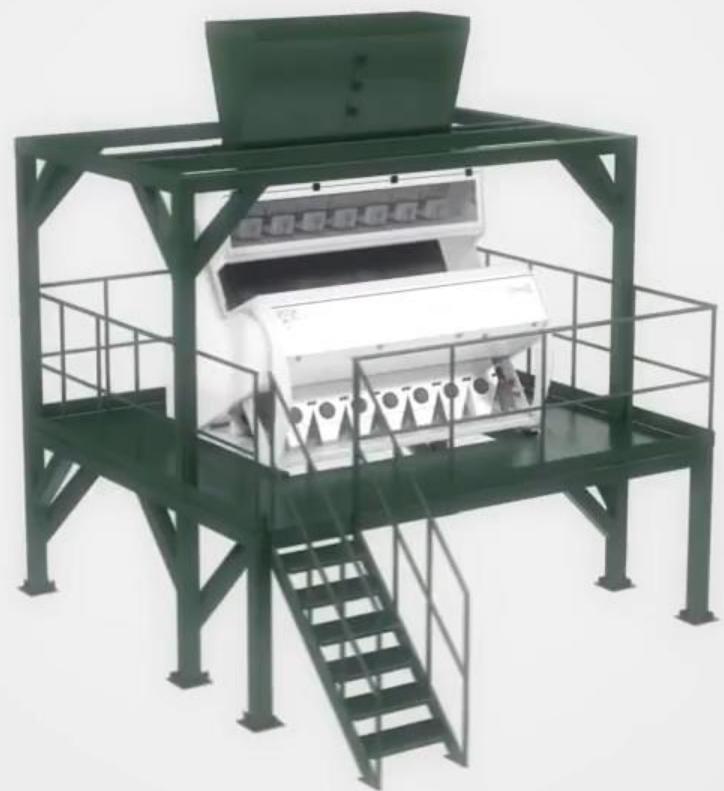


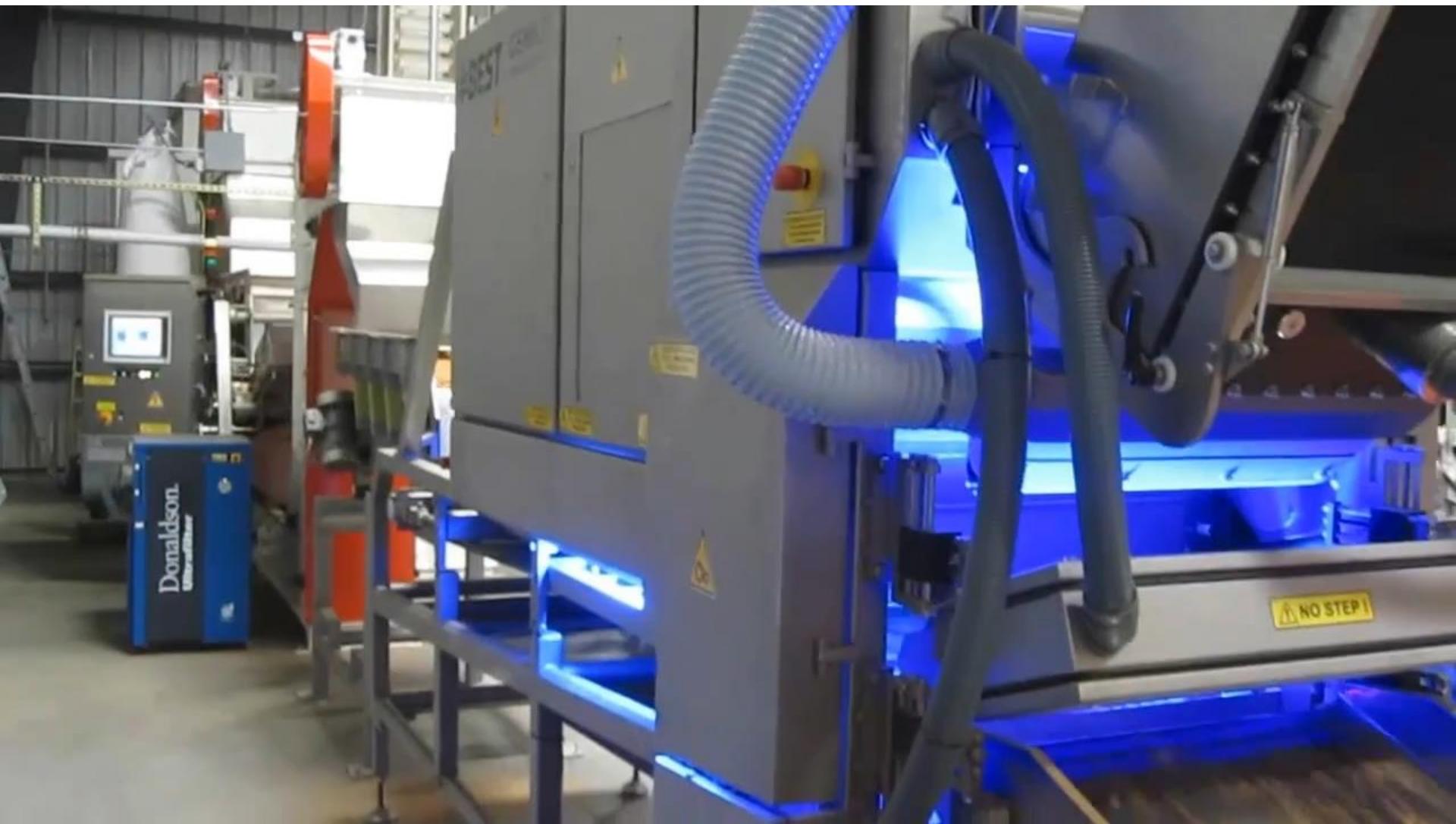
# Conclusiones

- Sí se puede
- Hay que hacerlo mejor
- No se puede usar una webcam

# ¿Preguntas?









# Arrugada o marchita



# Astillada



Color malo



Color malo



# Deformada



Doble



# Fragmento



Lisa



# Manchada



Mitad



No almendra



No almendra



# Partida



# Podrida o con daño de insectos



# Puntos marrones



# Raspada



# Sucia



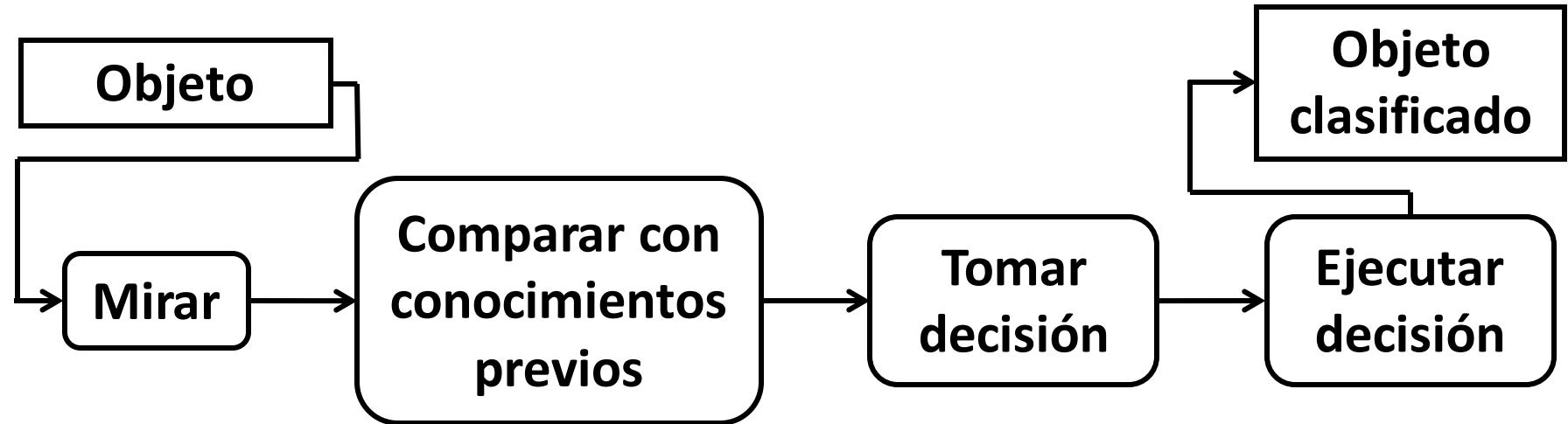
# Mal tamaño



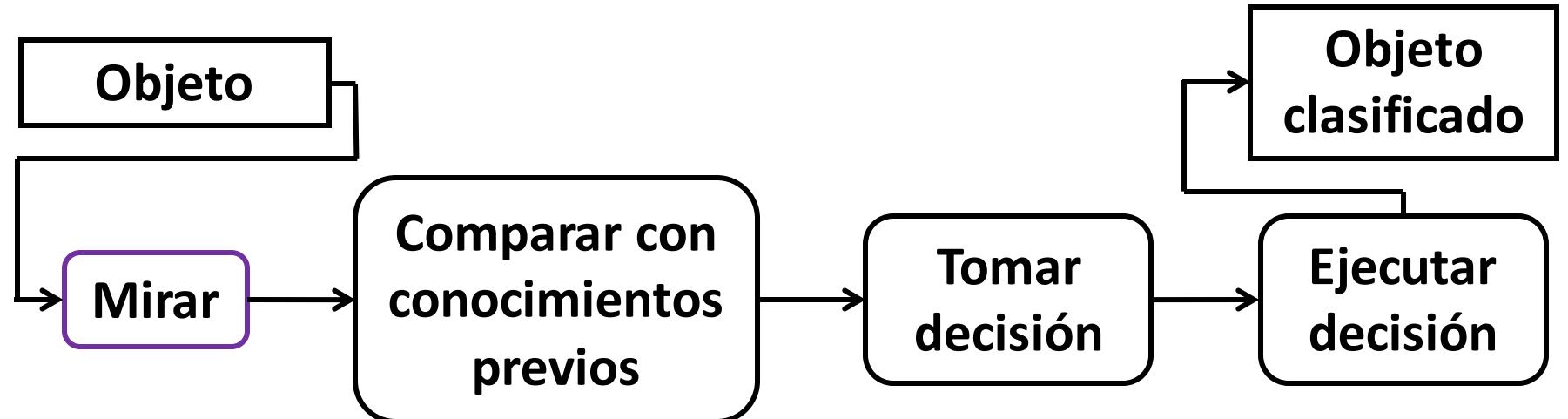
Mal tamaño



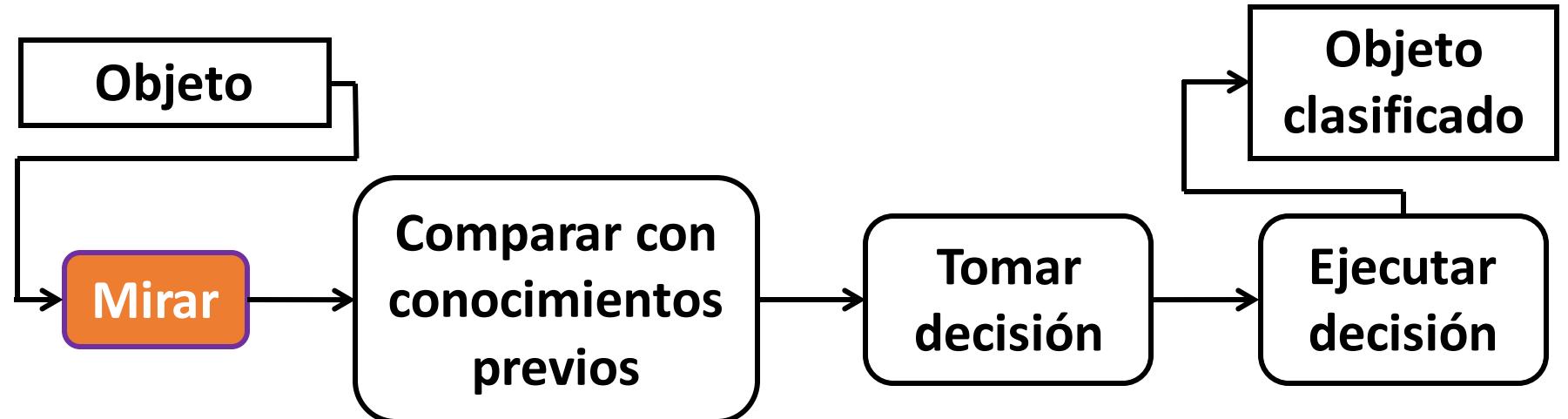






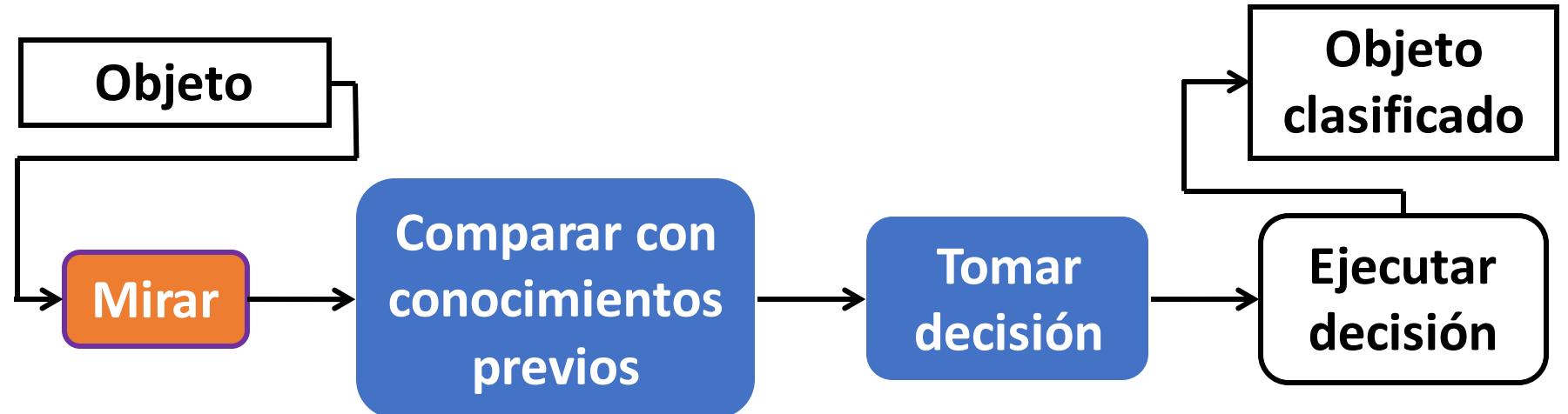




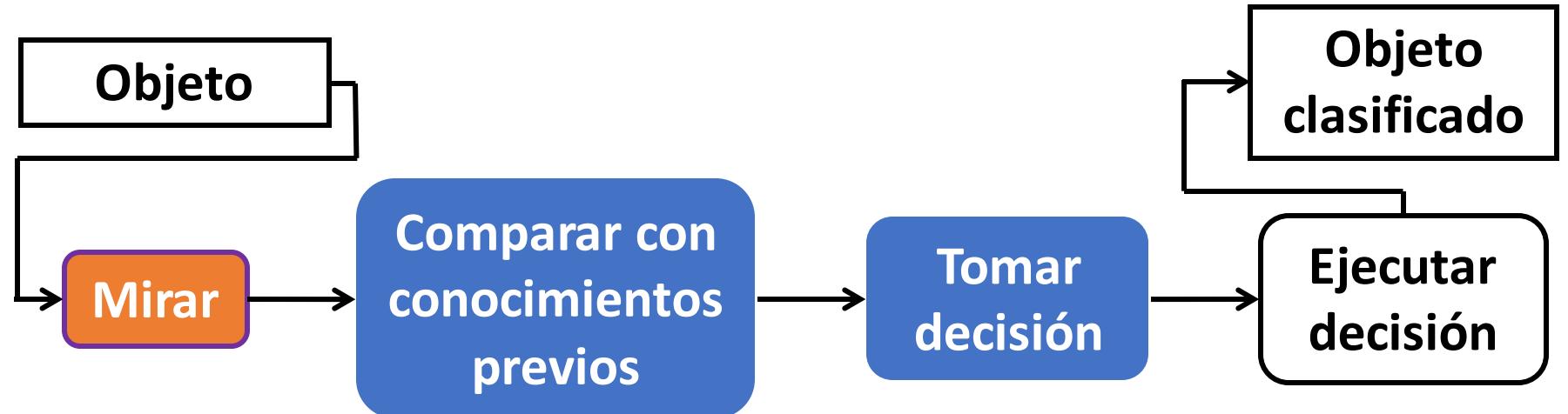


$$V = ( \text{medida1} ; \text{medida2}; \text{medida3}; \dots ; \text{medidaN} )$$



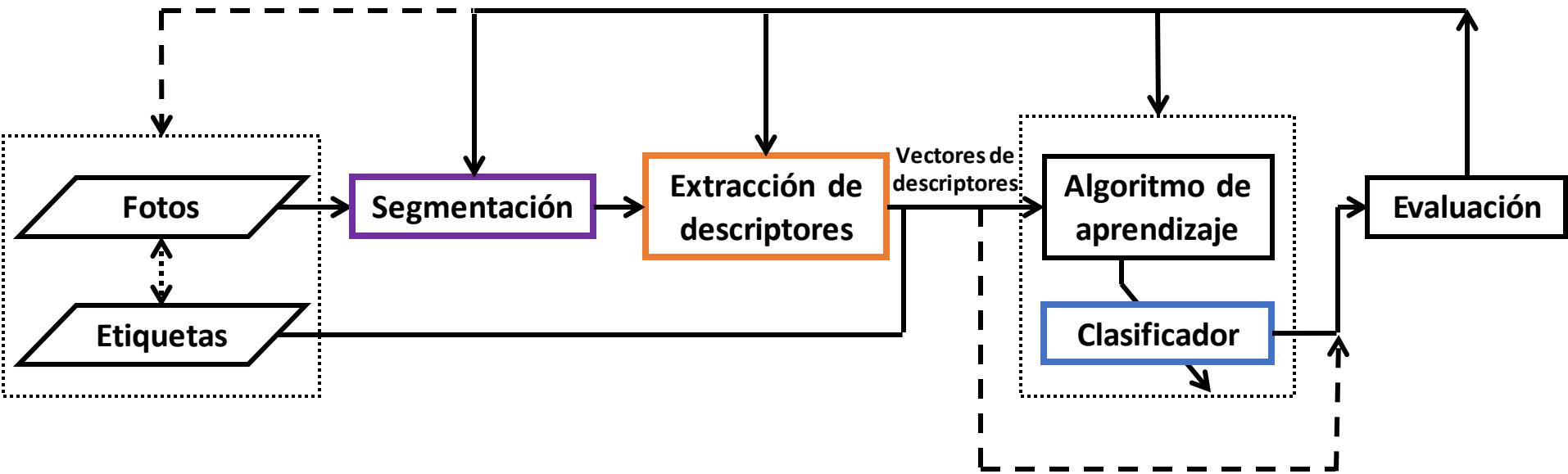






# PREDICCIÓN





## ENTRENAMIENTO

## PREDICCIÓN



A large snowman stands in a snowy forest. It has a wide, toothy grin made of dark stones, a green wreath on its head, and a small black bow tie. The background is filled with bare trees covered in snow.

Want to tag Juan Román  
Riquelme?

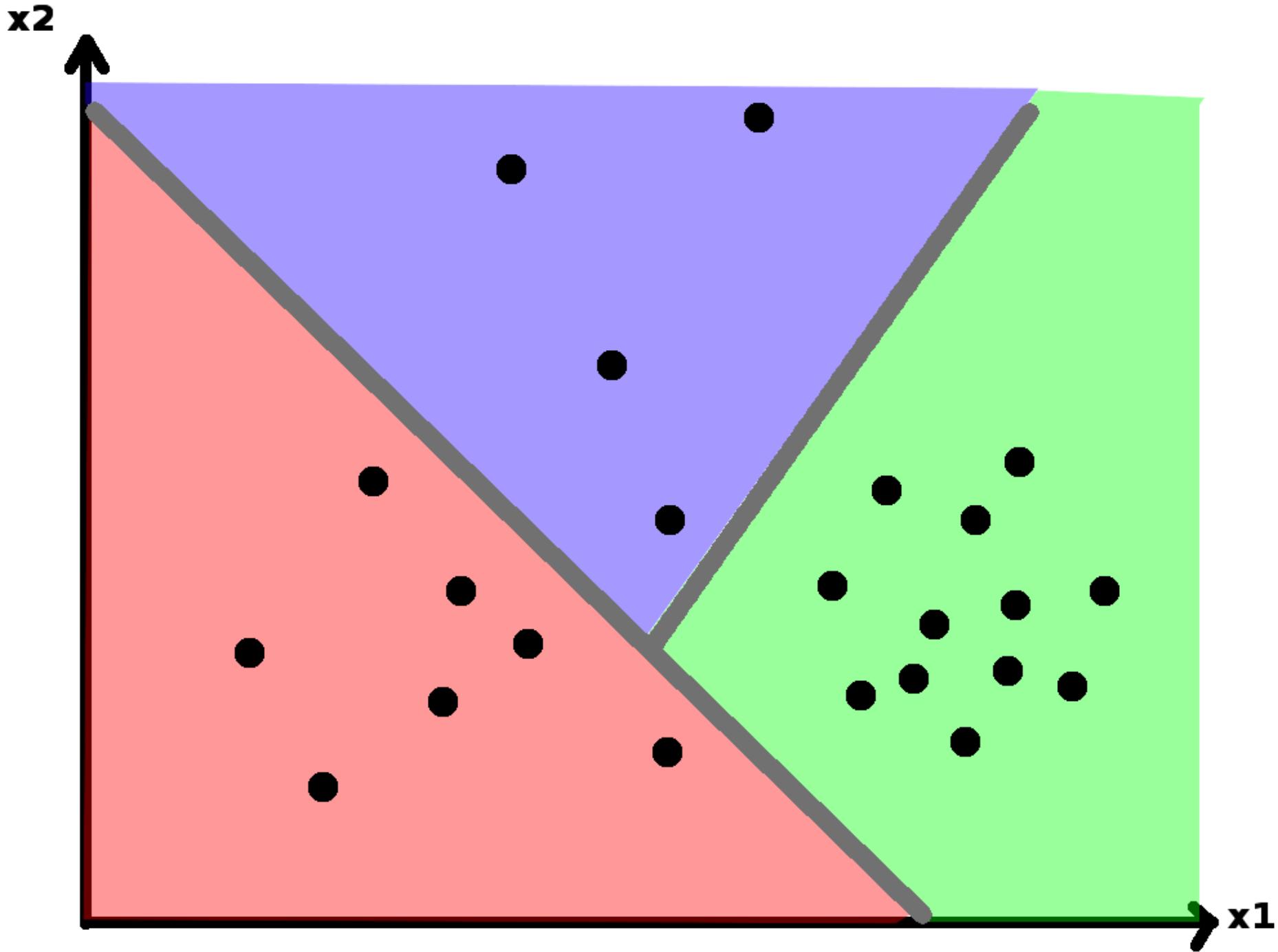
Yes - No



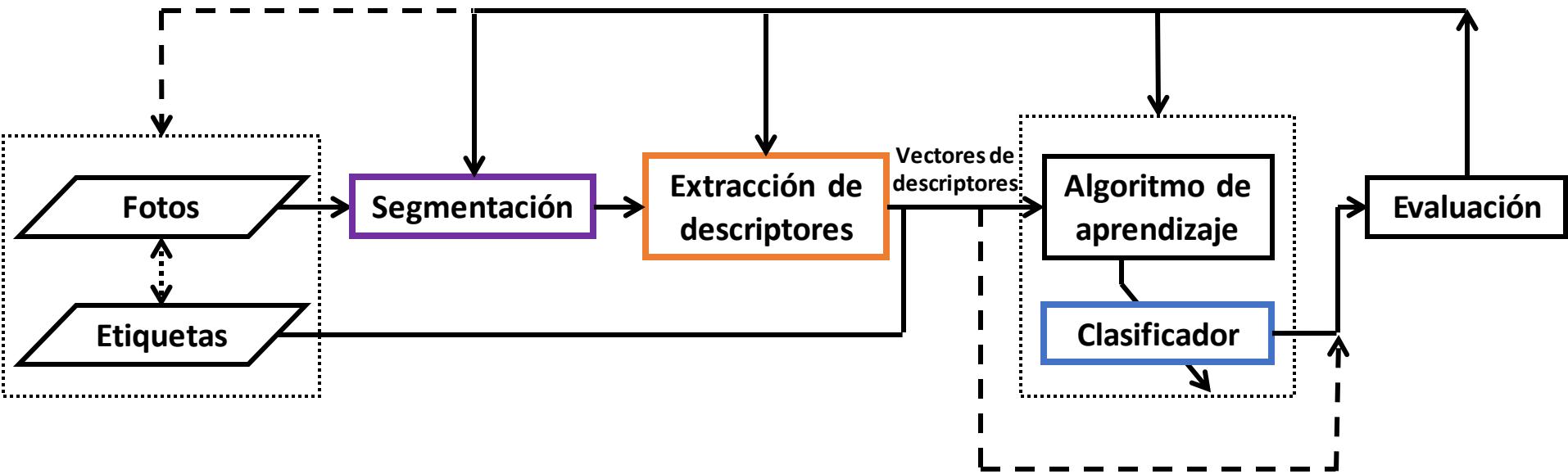
$V = ( medida1 ; medida2; medida3; \dots ; medidaN )$

$V = ( kilómetros\_mensuales ; ingresos\_mensuales )$

$x_2$  $x_1$



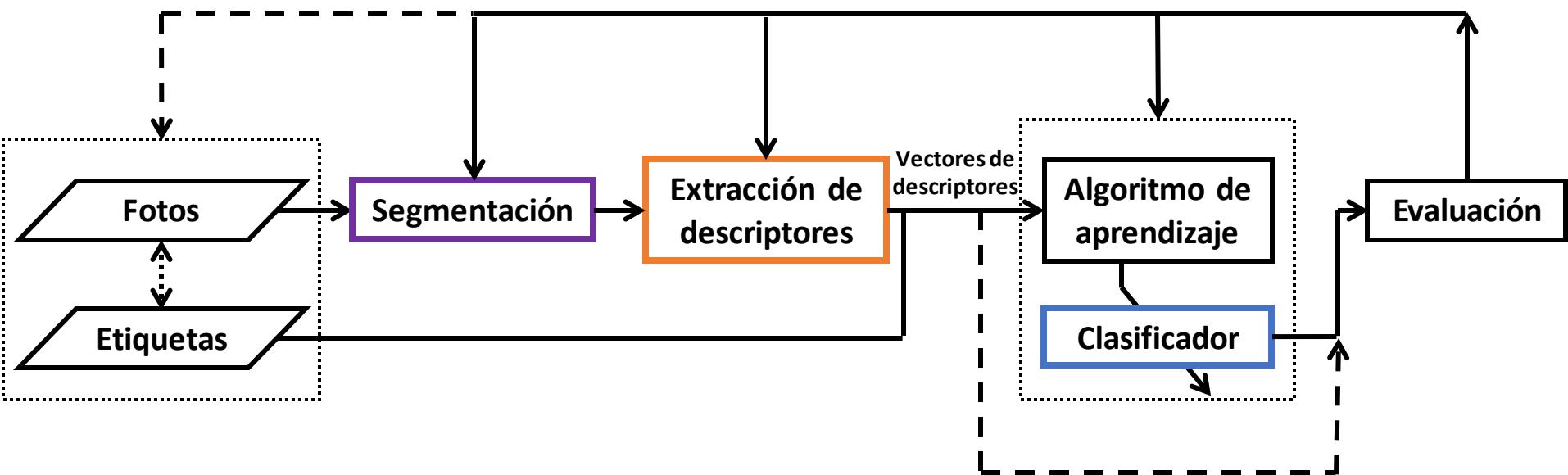




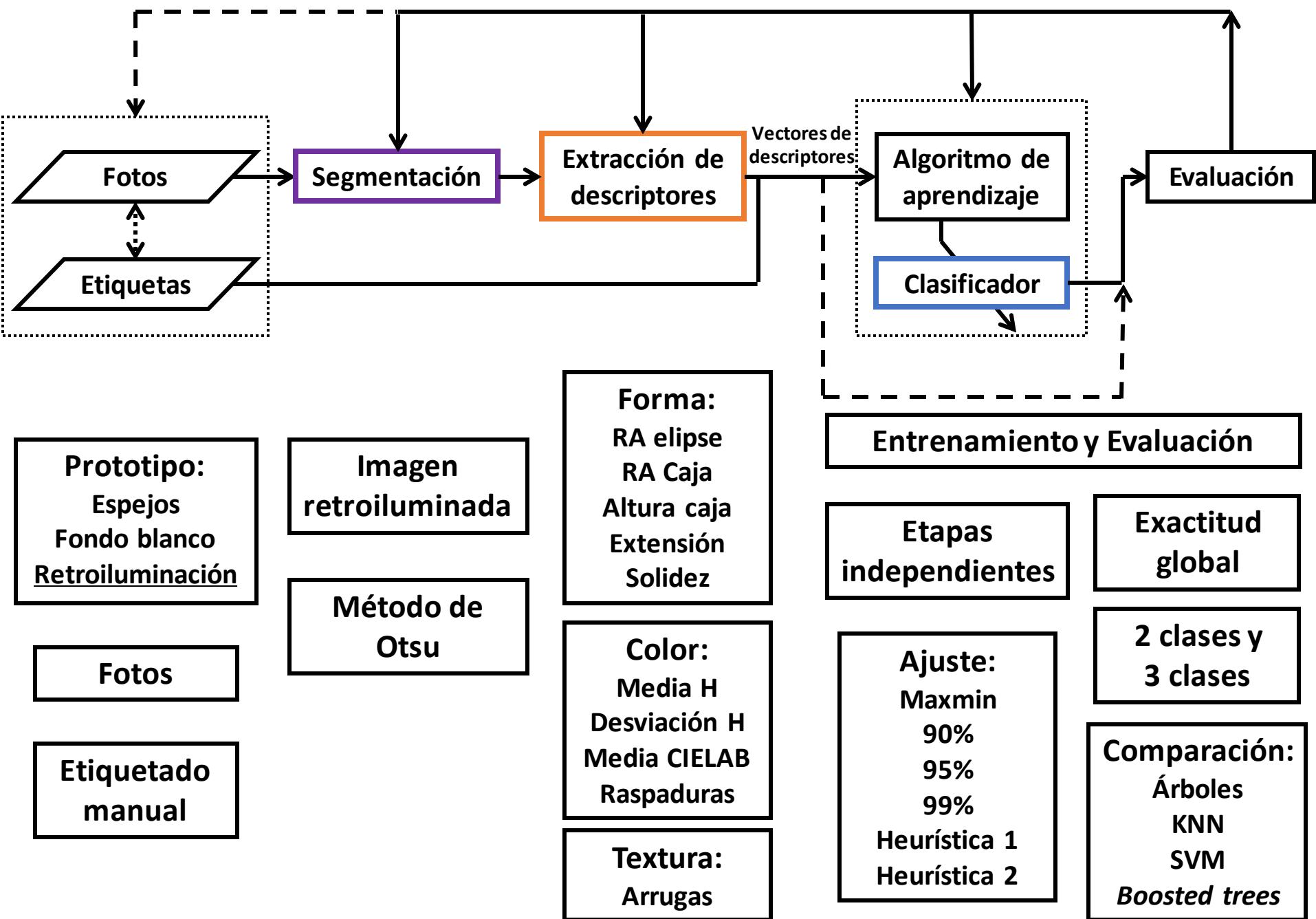
## ENTRENAMIENTO PREDICCIÓN



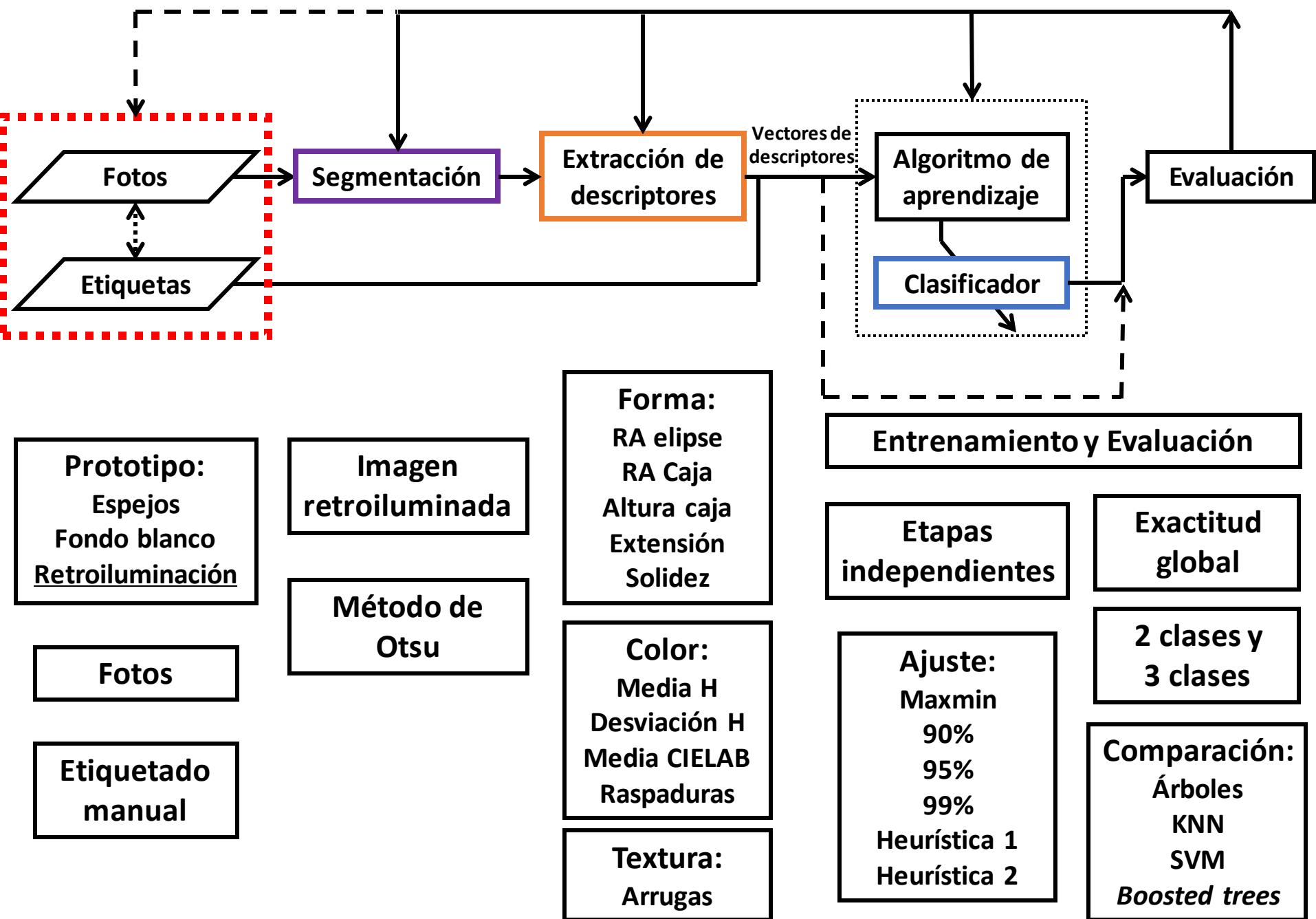
# Aprendizaje supervisado: entrenamiento



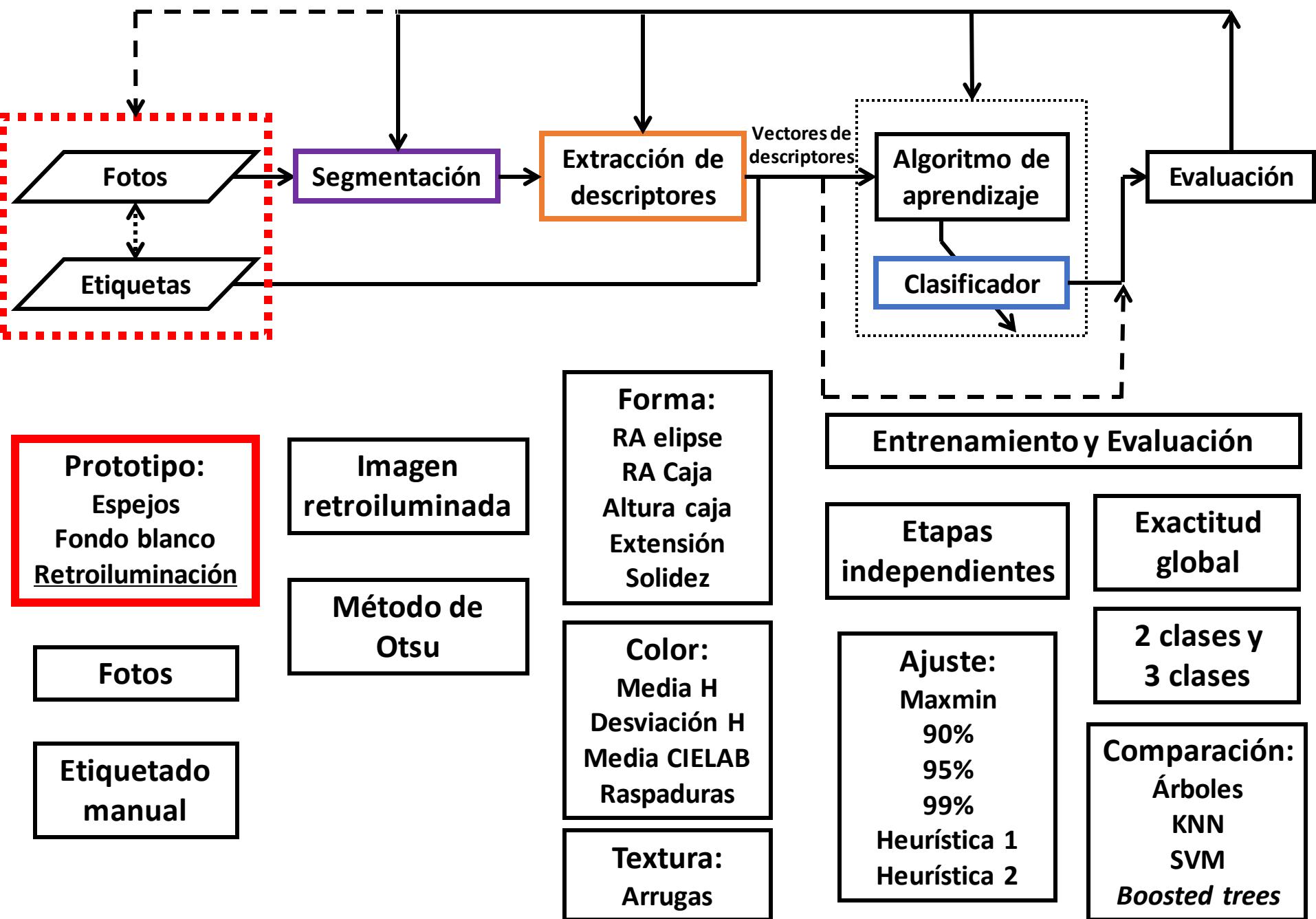
# Aprendizaje supervisado: entrenamiento



# Aprendizaje supervisado: entrenamiento

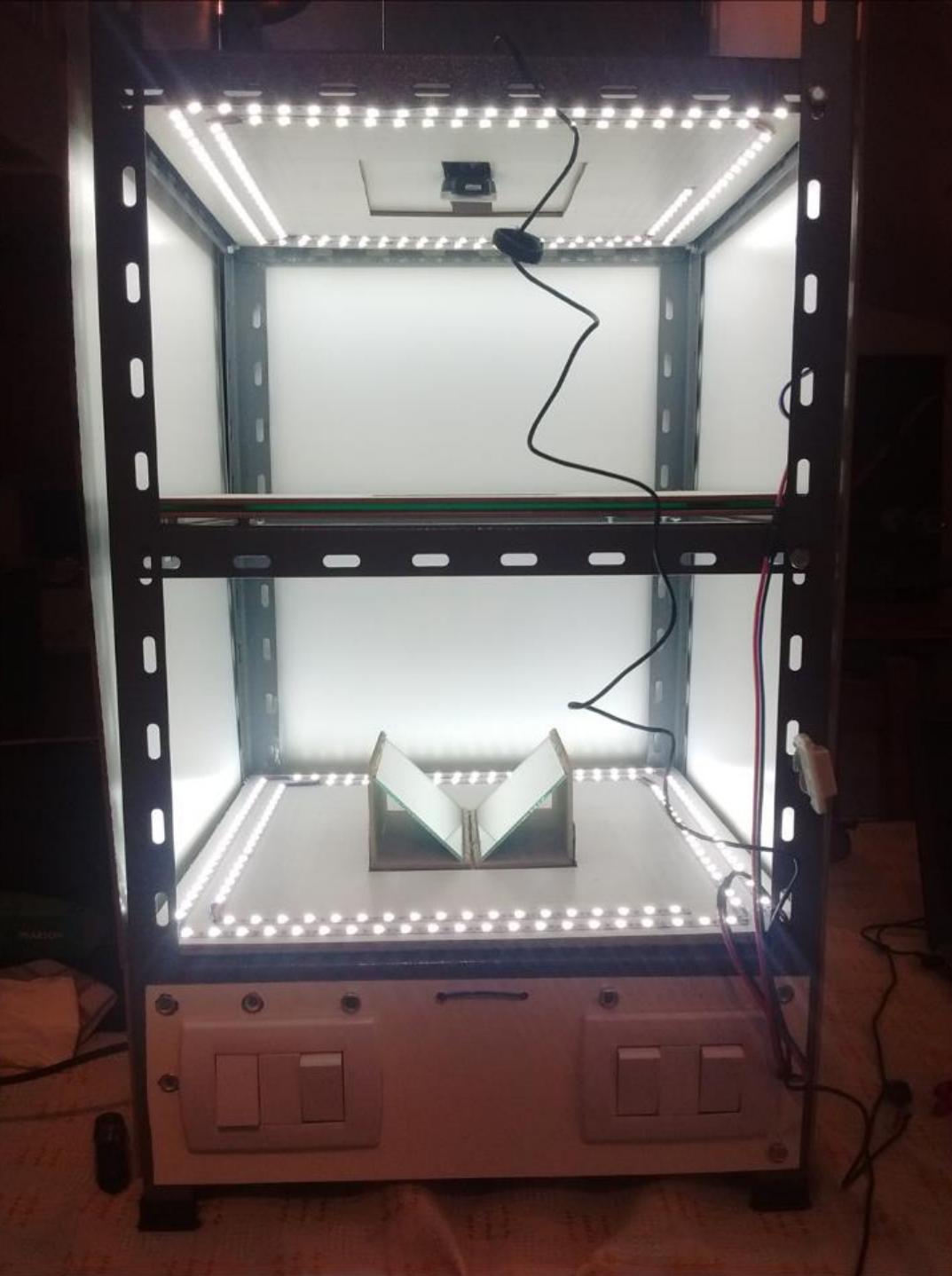
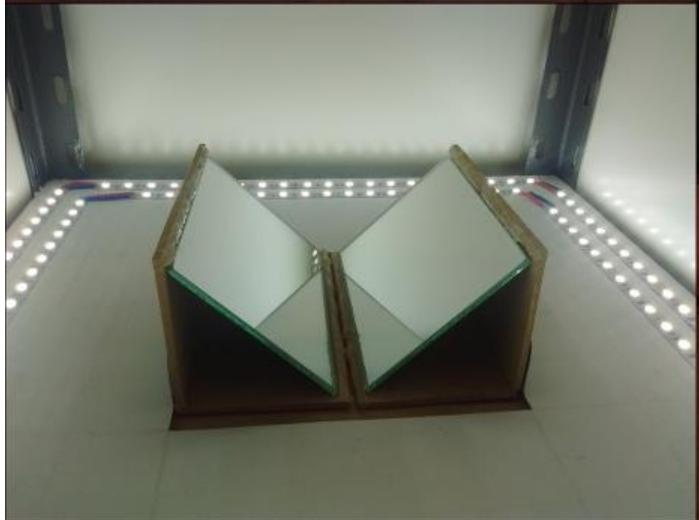
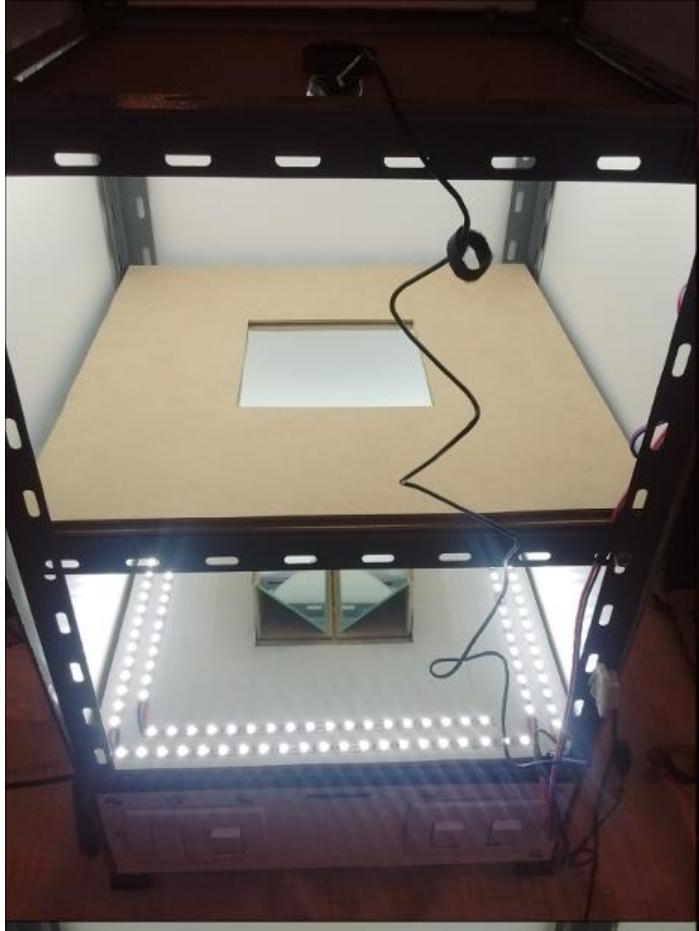


# Aprendizaje supervisado: entrenamiento

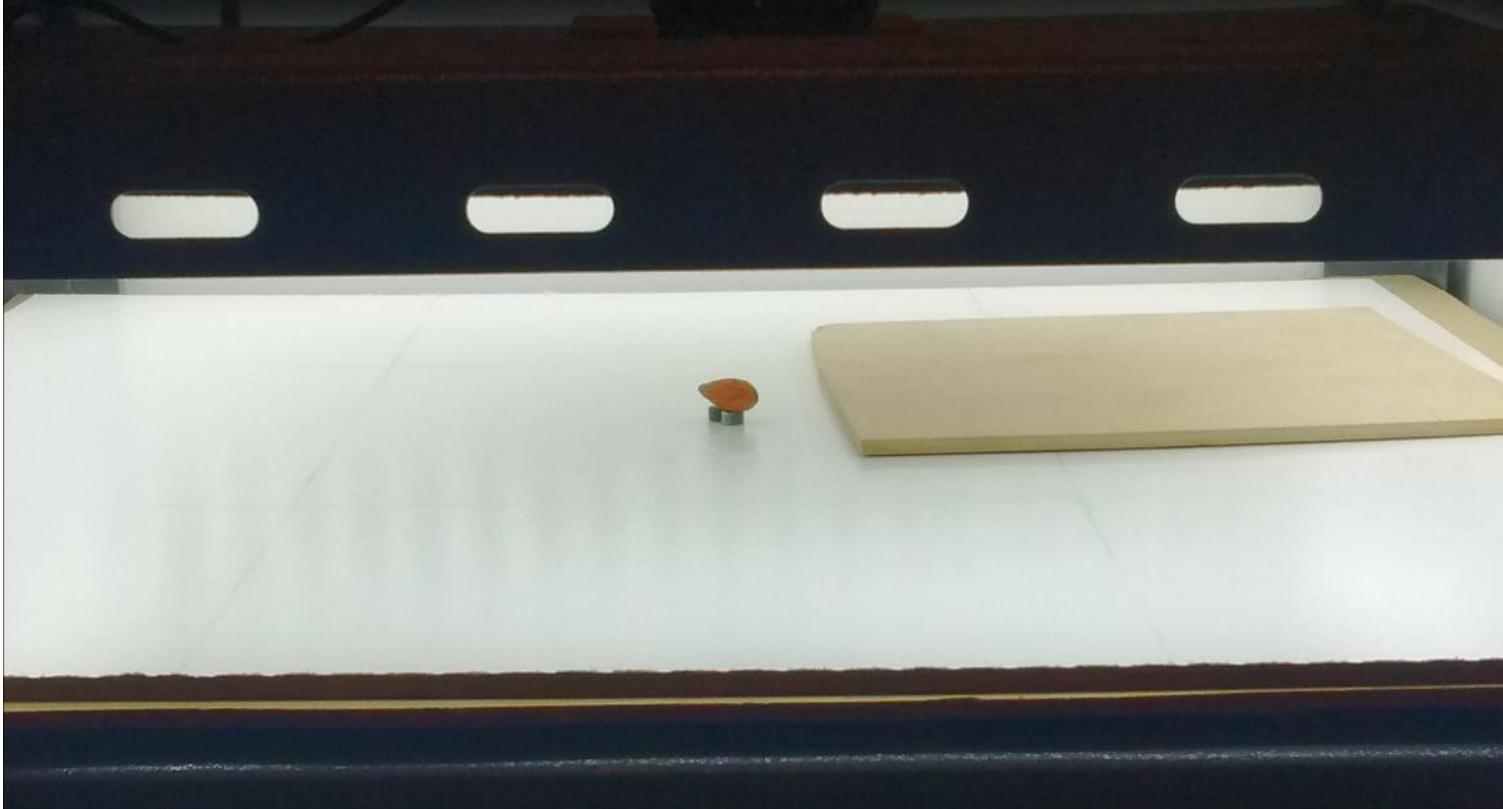






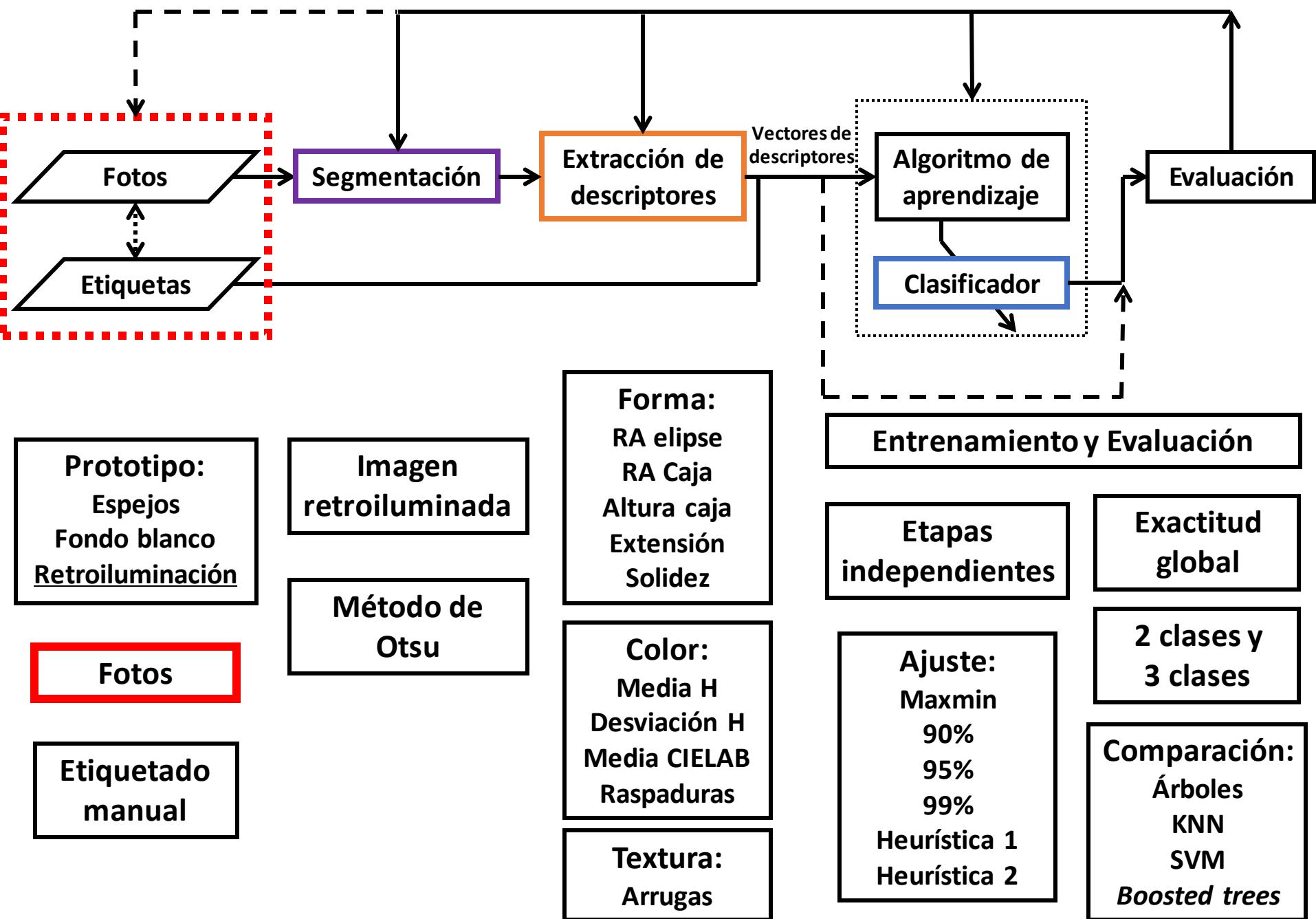






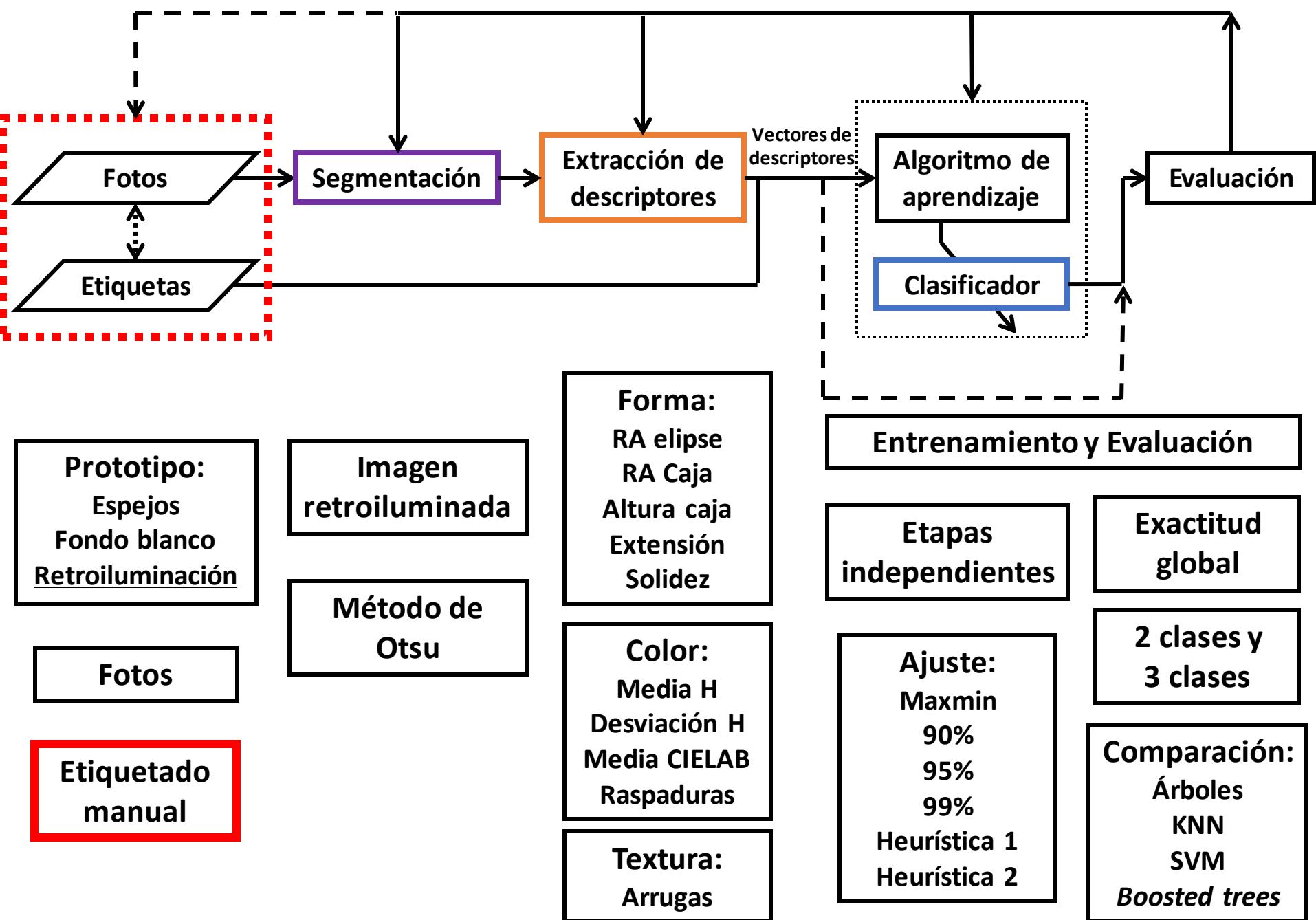


# Aprendizaje supervisado: entrenamiento





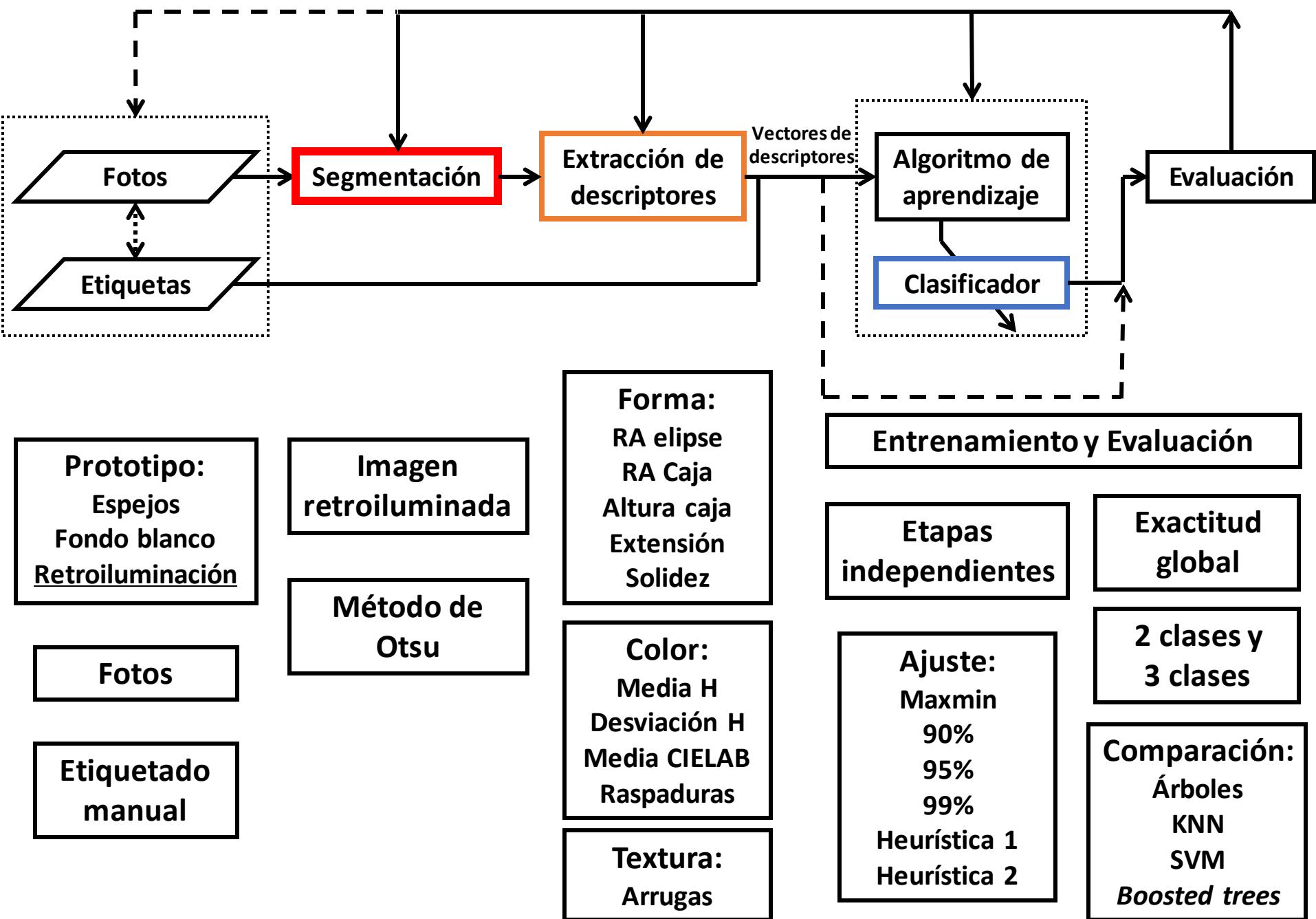
# Aprendizaje supervisado: entrenamiento

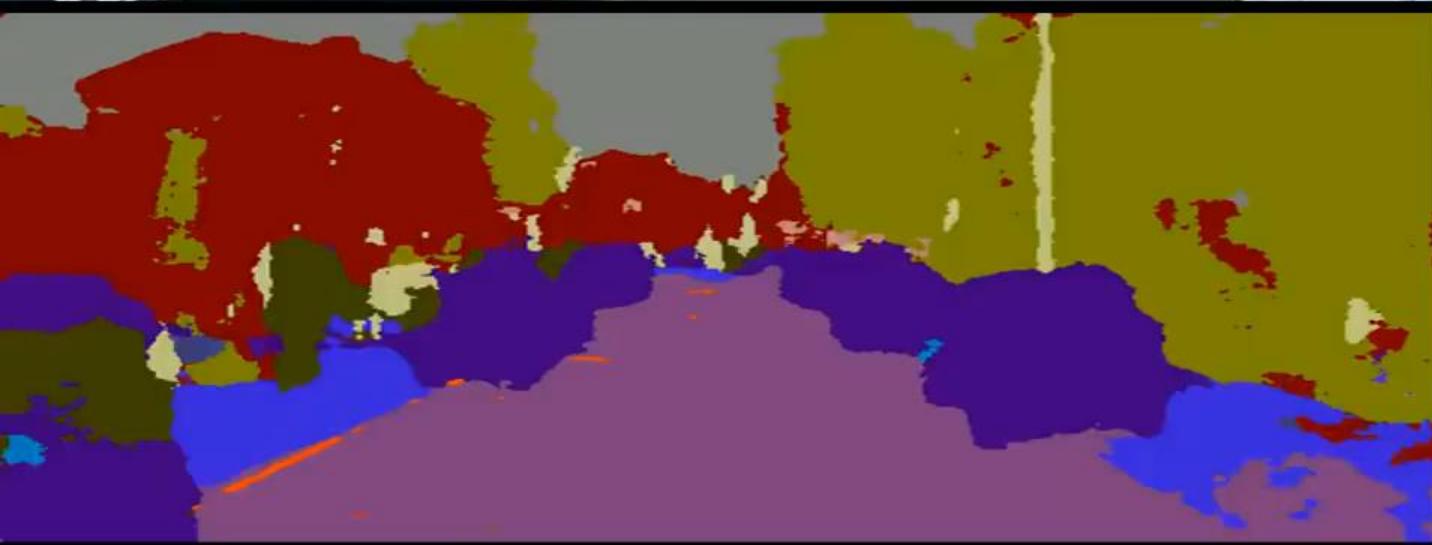




- Resolución 1352/1967 del Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA)
  - Parcialmente en Código Alimentario Argentino
- “Estándar estadounidense para la calidad de almendras peladas” – USDA
- “Estándar DDP-06 acerca de la comercialización y control de calidad de semillas de almendra” – Comisión Económica de las Naciones Unidas para Europa (UNECE)

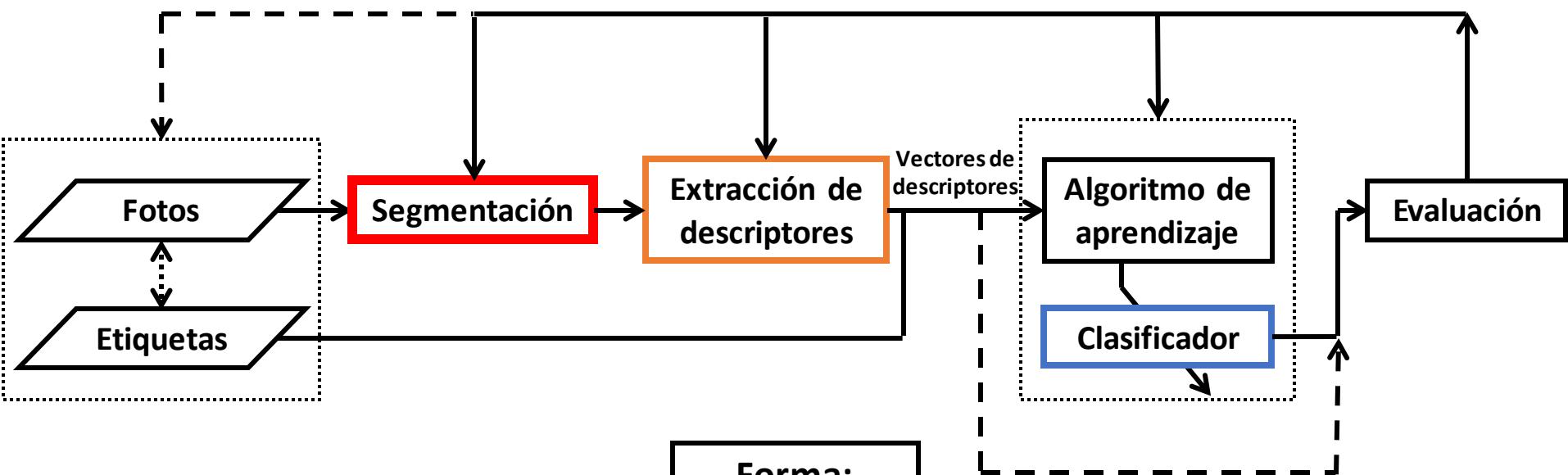
# Aprendizaje supervisado: entrenamiento





- Sky
- Building
- Pole
- Road Marking
- Road
- Pavement
- Tree
- Sign Symbol
- Fence
- Vehicle
- Pedestrian
- Bike

# Aprendizaje supervisado: entrenamiento



Prototipo:  
Espejos  
Fondo blanco  
Retroiluminación

Imagen retroiluminada

Método de Otsu

Fotos

Etiquetado manual

**Forma:**  
RA elipse  
RA Caja  
Altura caja  
Extensión  
Solidez

**Color:**  
Media H  
Desviación H  
Media CIELAB  
Raspaduras

**Textura:**  
Arrugas

Entrenamiento y Evaluación

Etapas independientes

Exactitud global

2 clases y 3 clases

Ajuste:  
Maxmin  
90%  
95%  
99%

Heurística 1  
Heurística 2

Comparación:  
Árboles  
KNN  
SVM  
*Boosted trees*

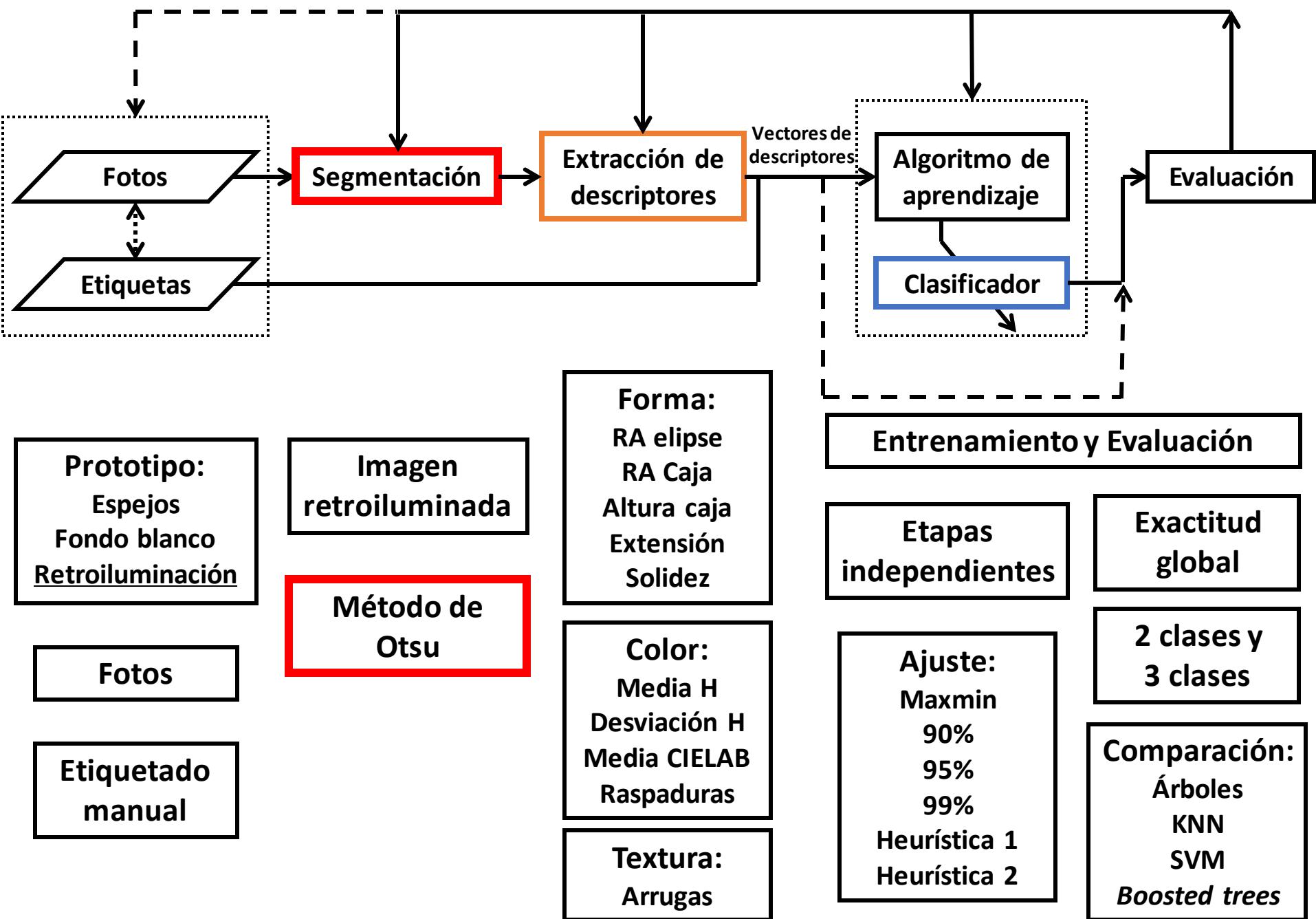








# Aprendizaje supervisado: entrenamiento

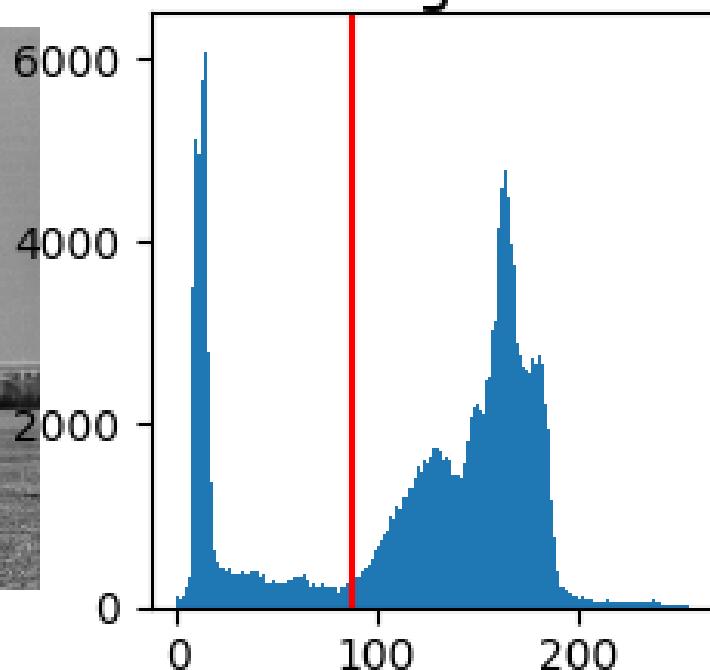


# Método de Otsu

Original



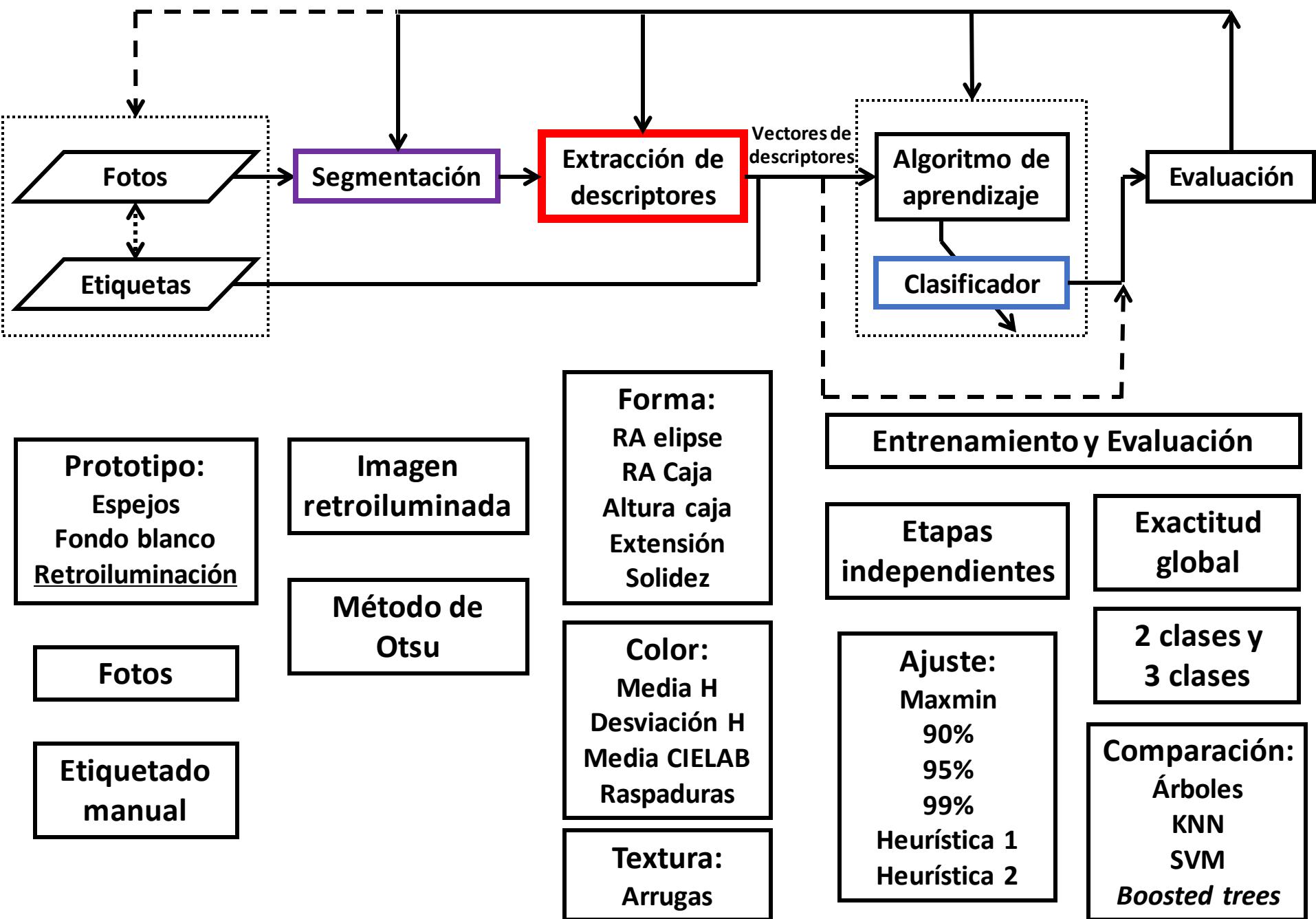
Histograma



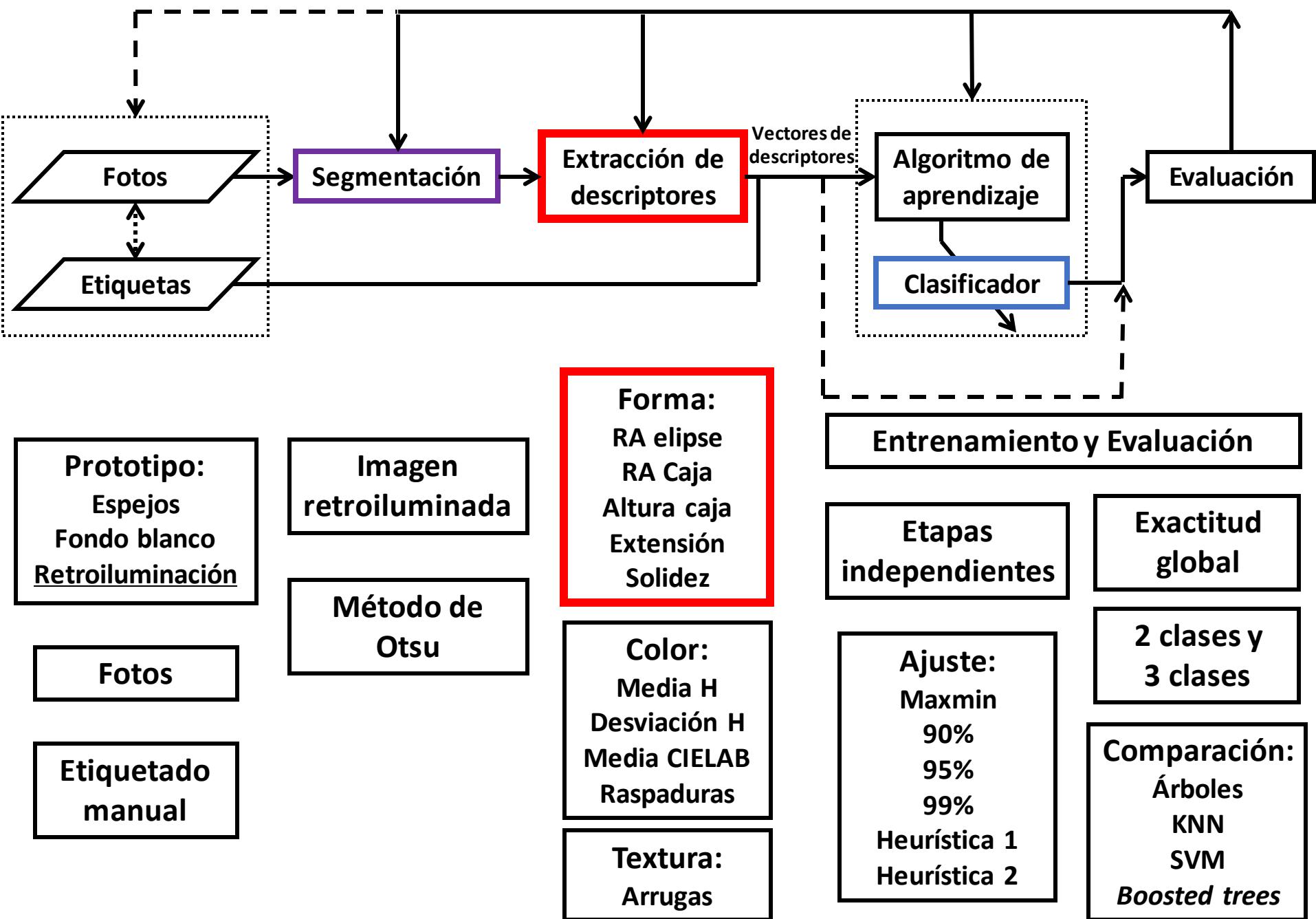
Umbralizada



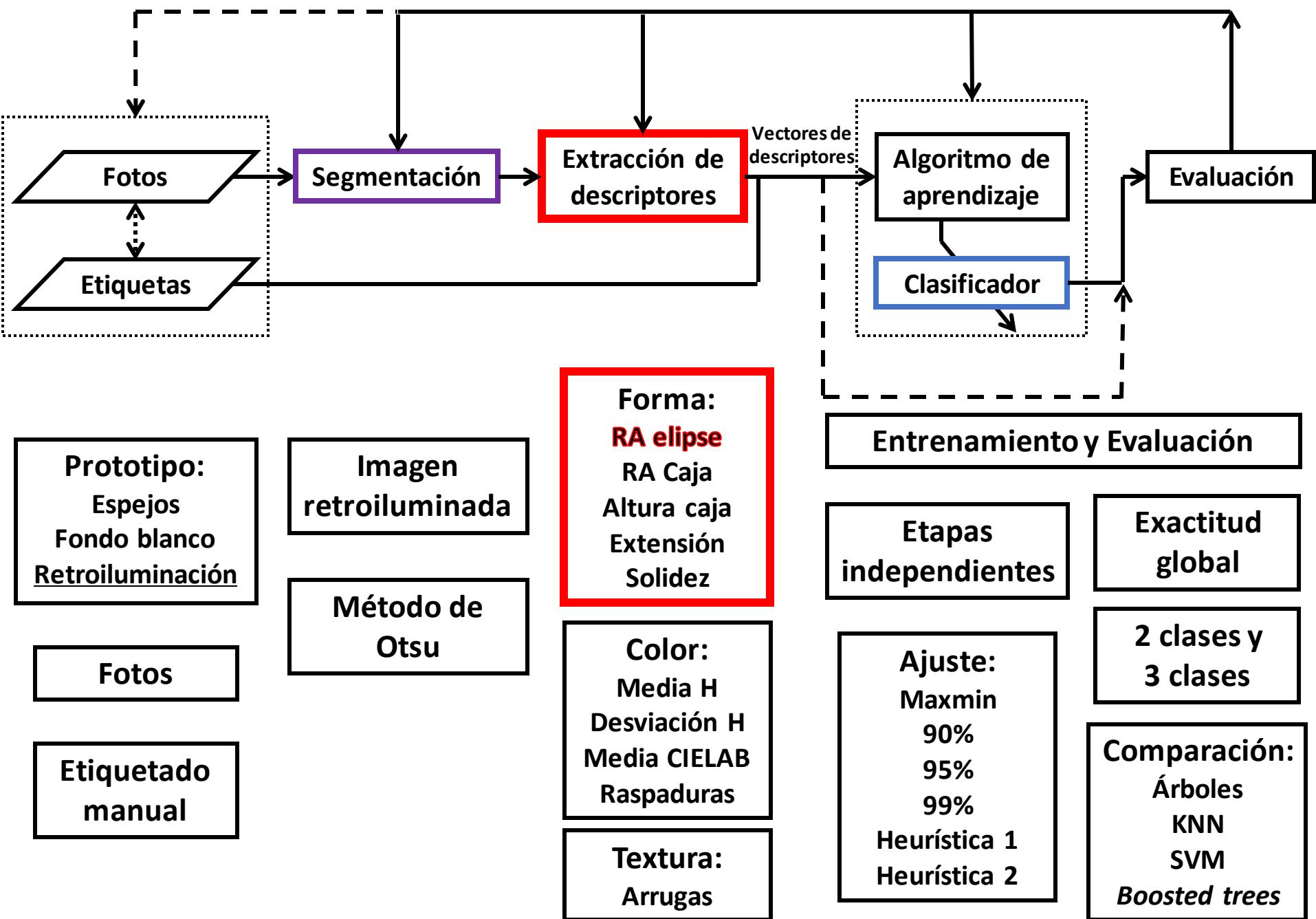
# Aprendizaje supervisado: entrenamiento

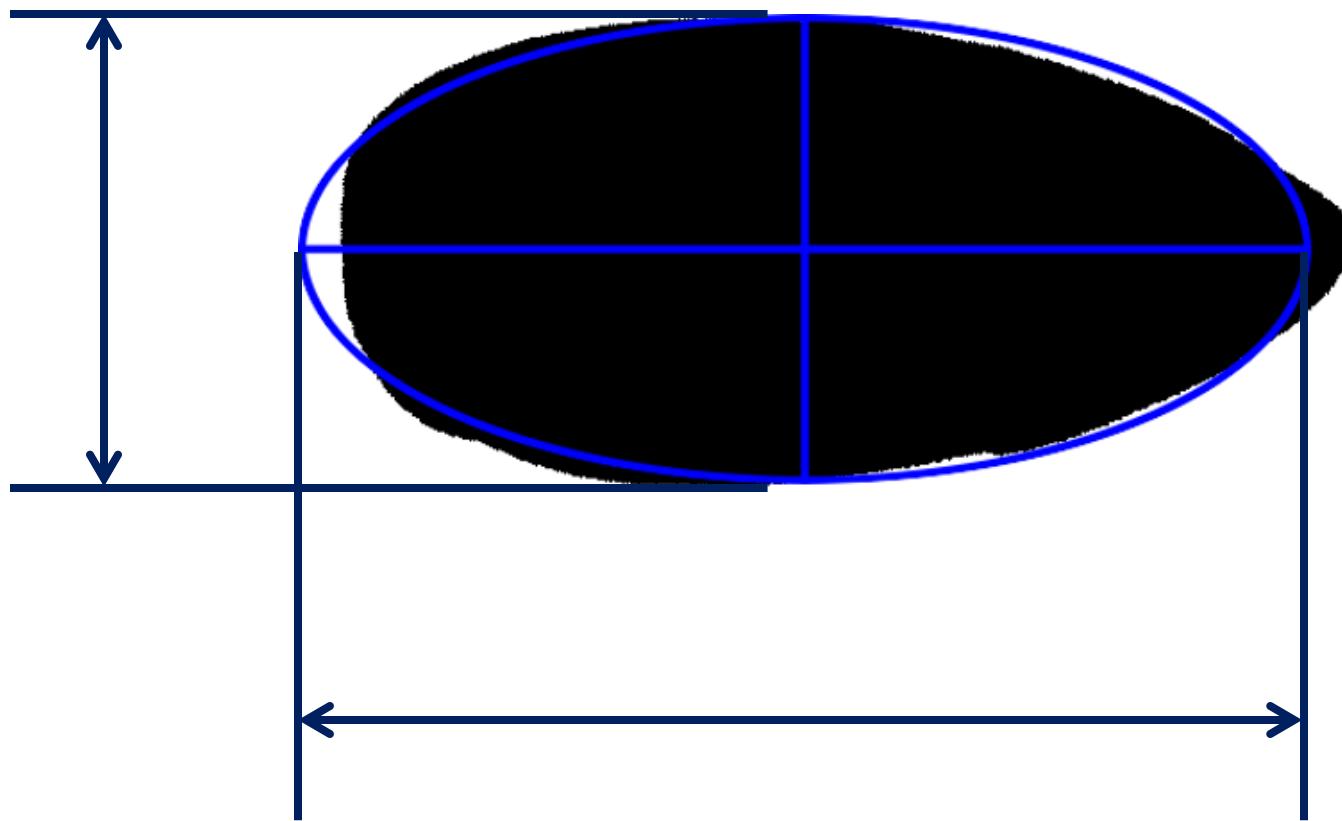


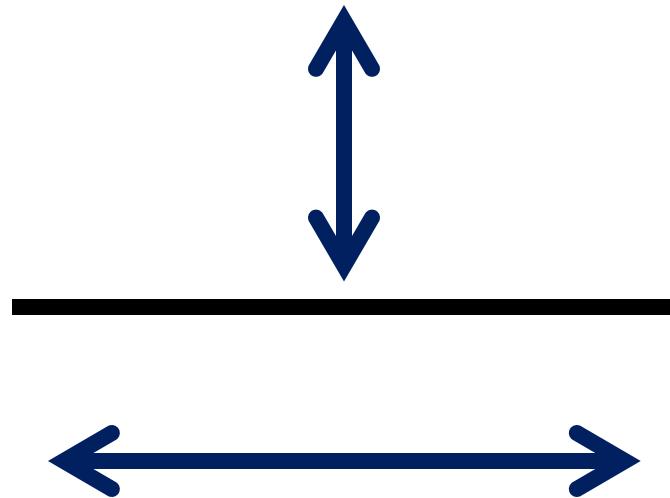
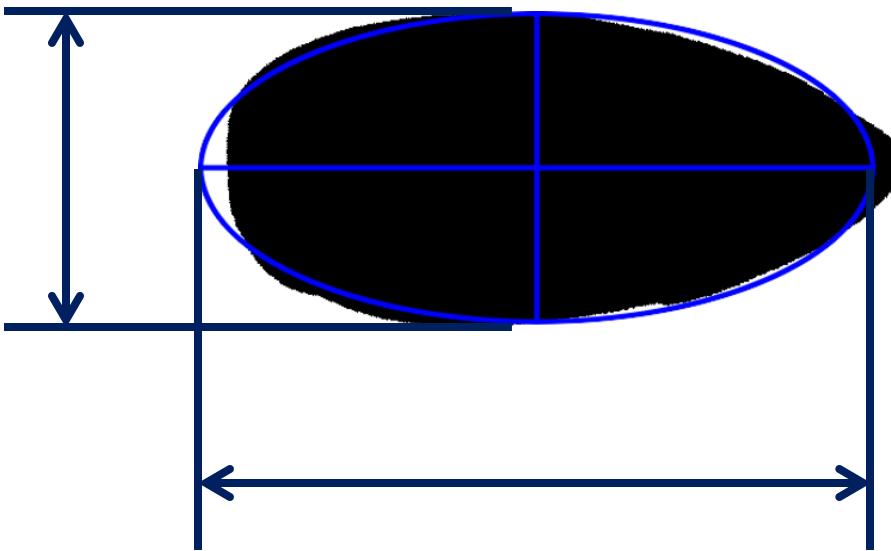
# Aprendizaje supervisado: entrenamiento



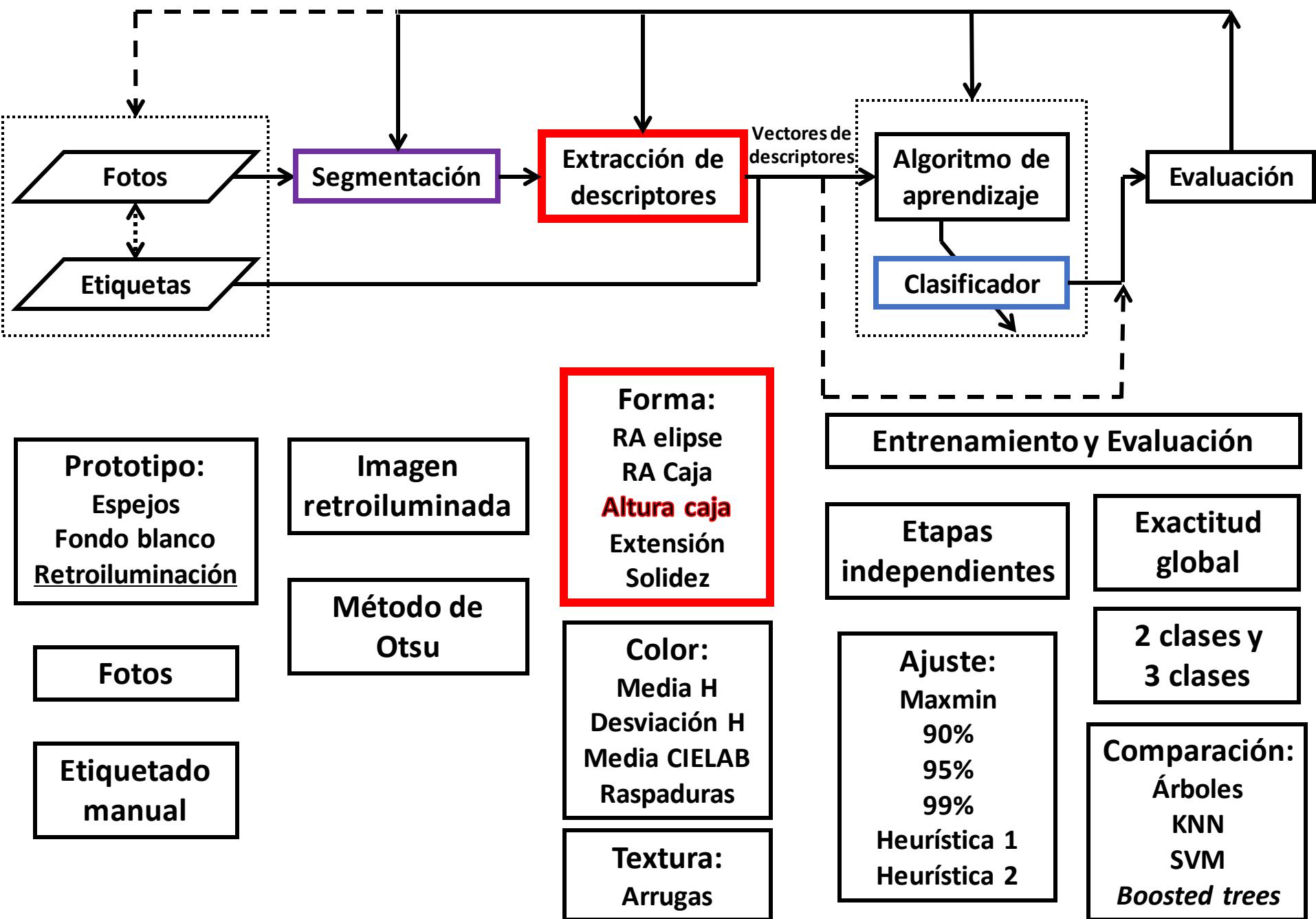
# Aprendizaje supervisado: entrenamiento

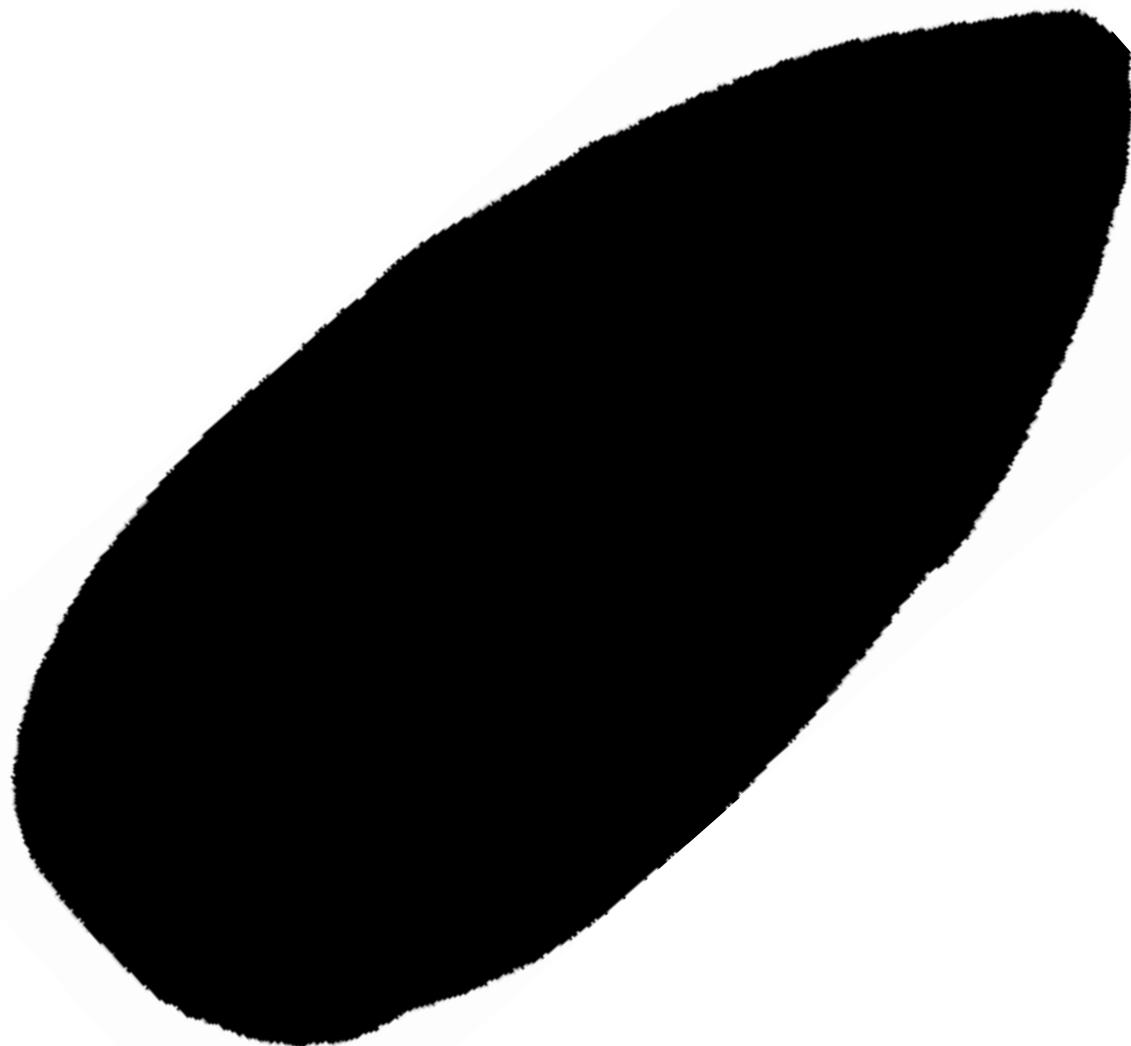


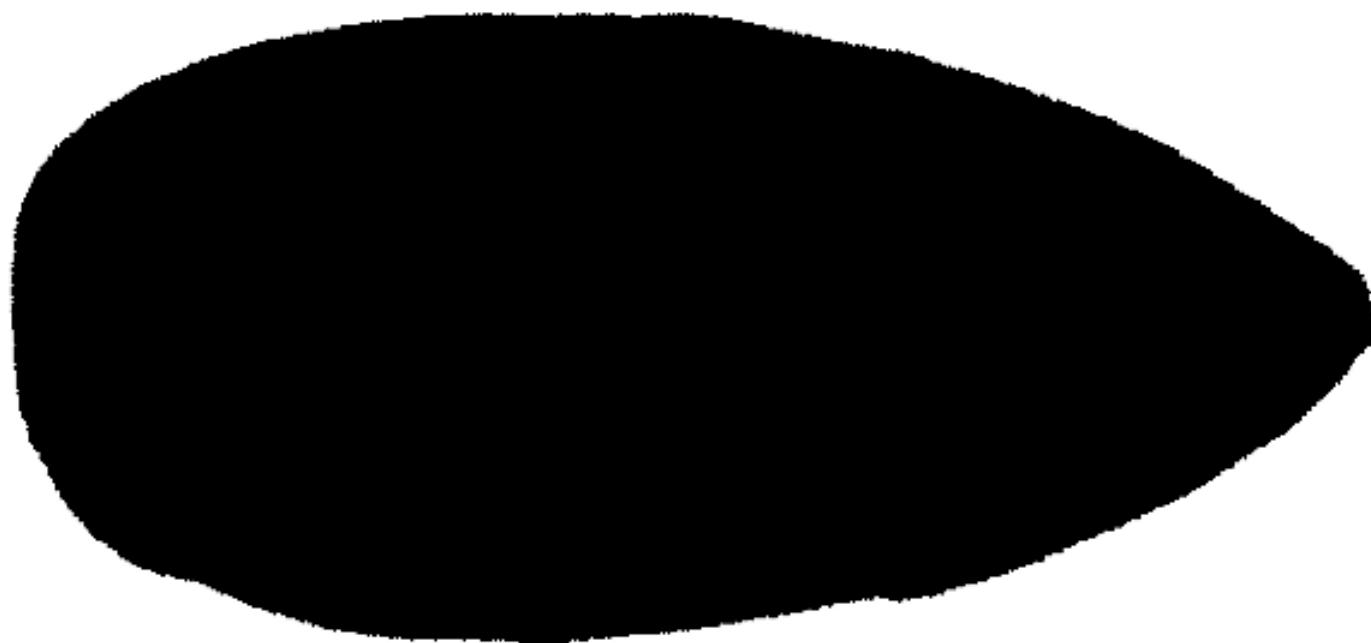


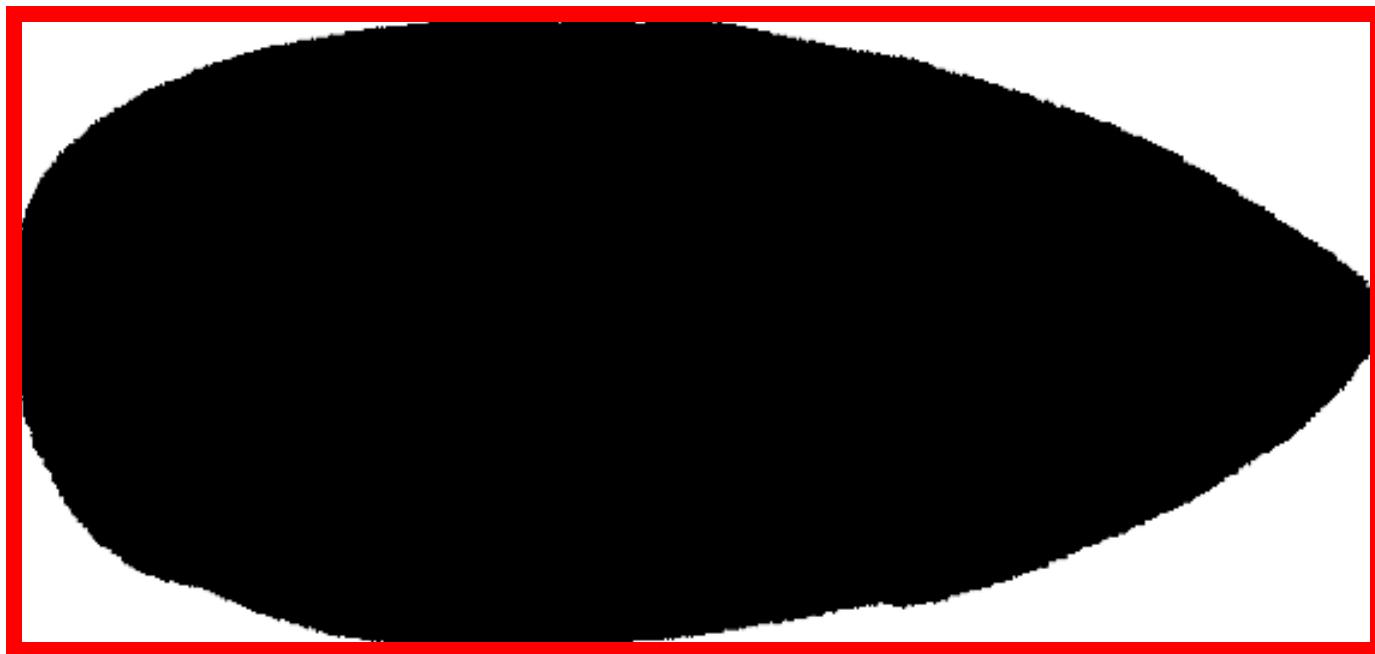


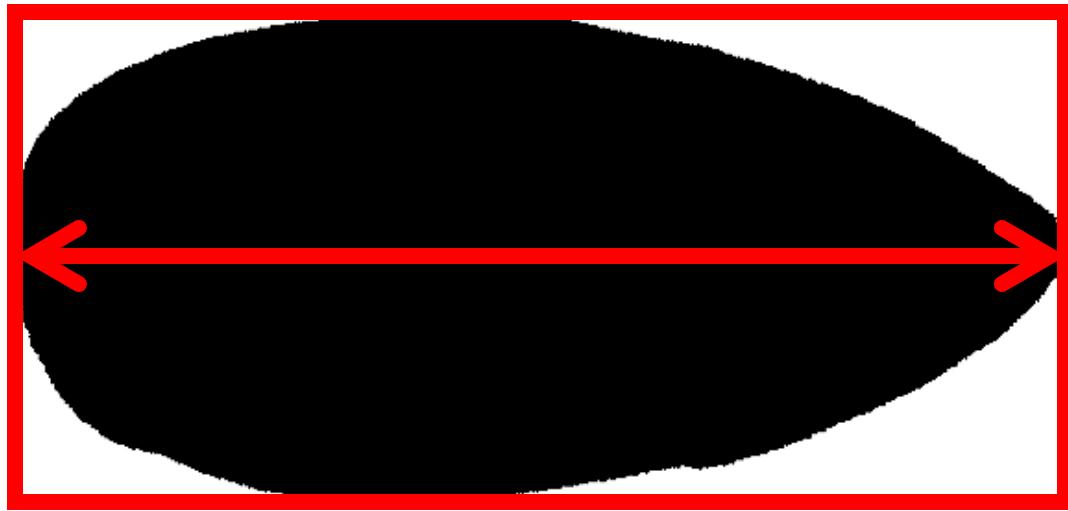
# Aprendizaje supervisado: entrenamiento



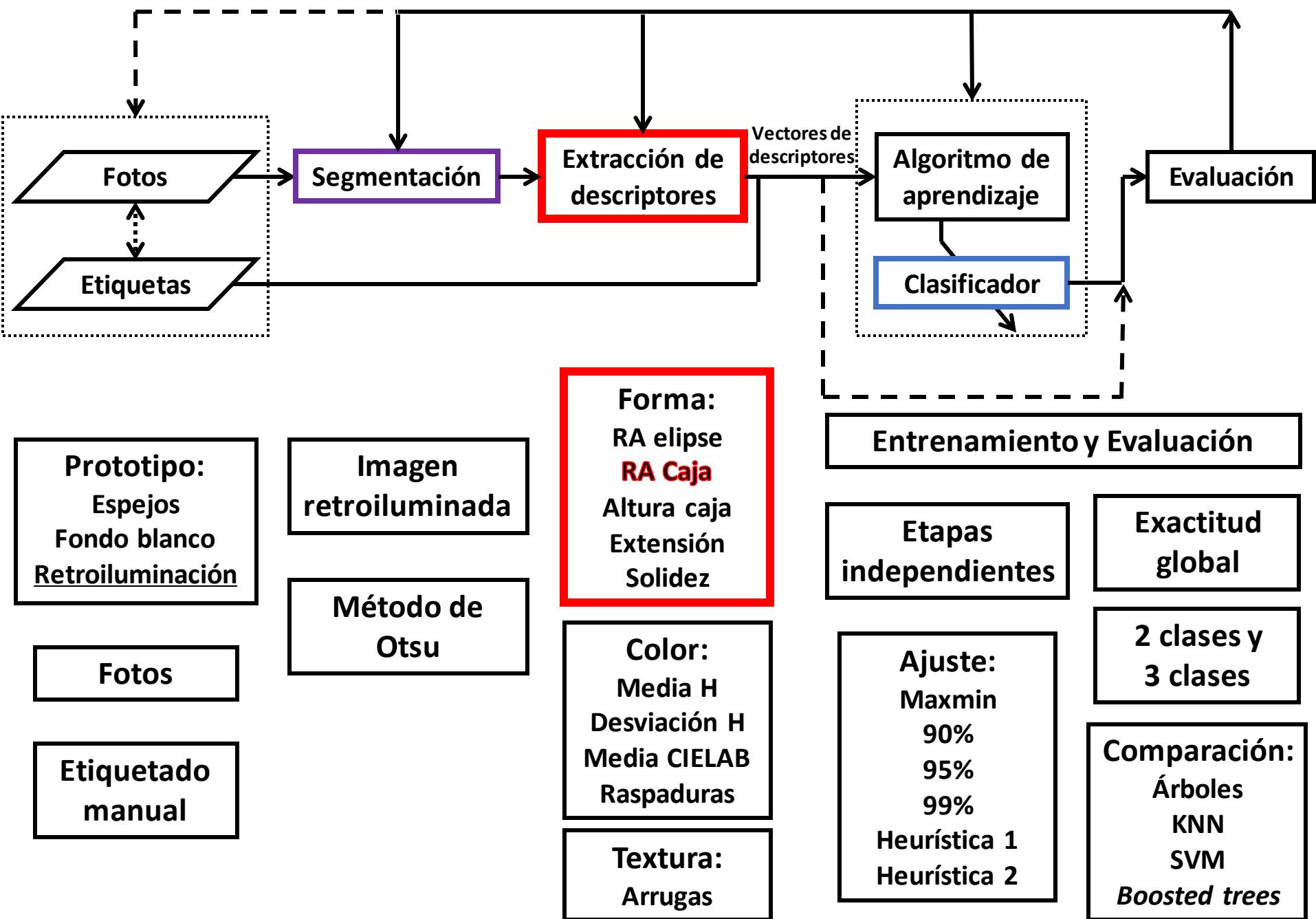


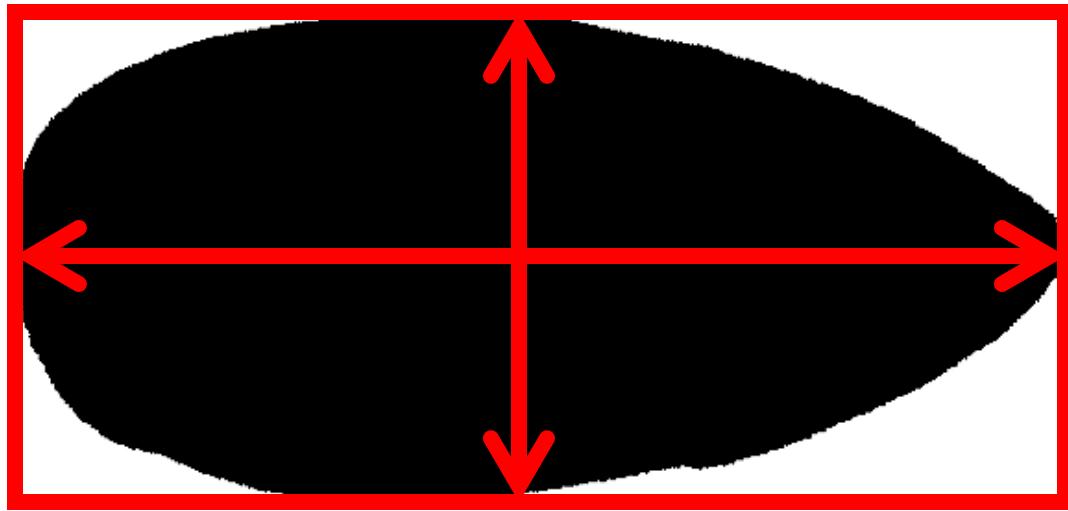


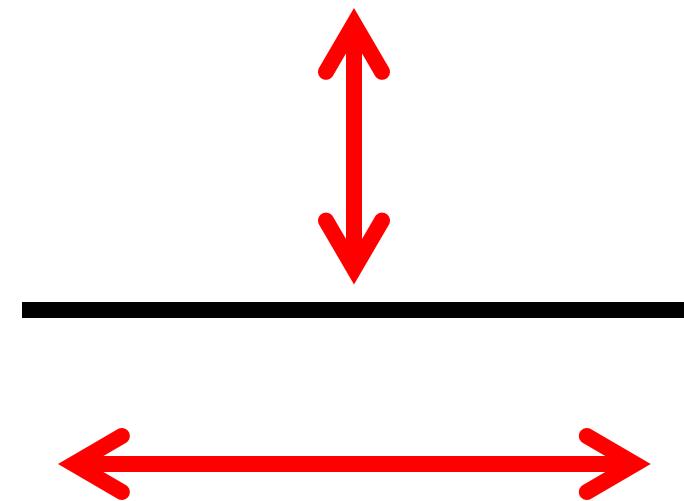
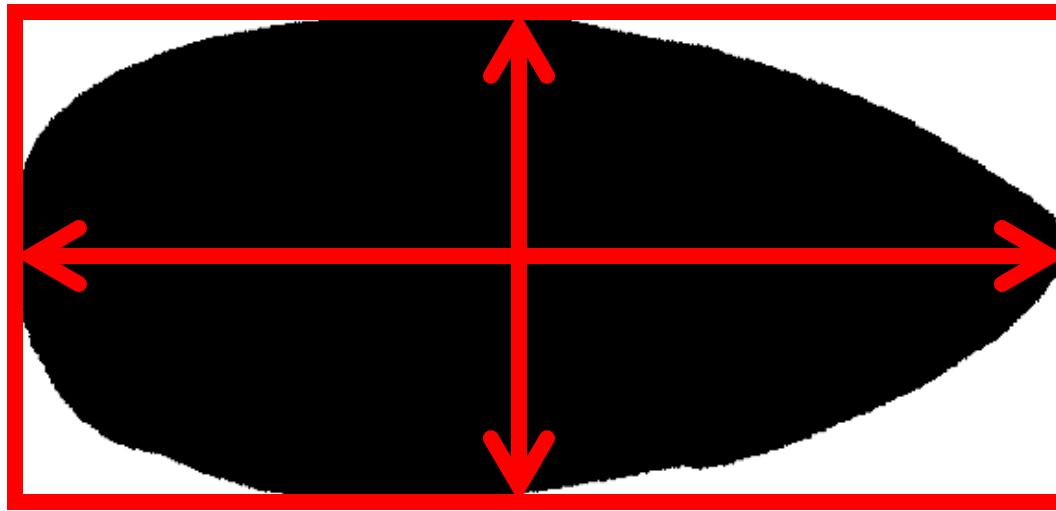




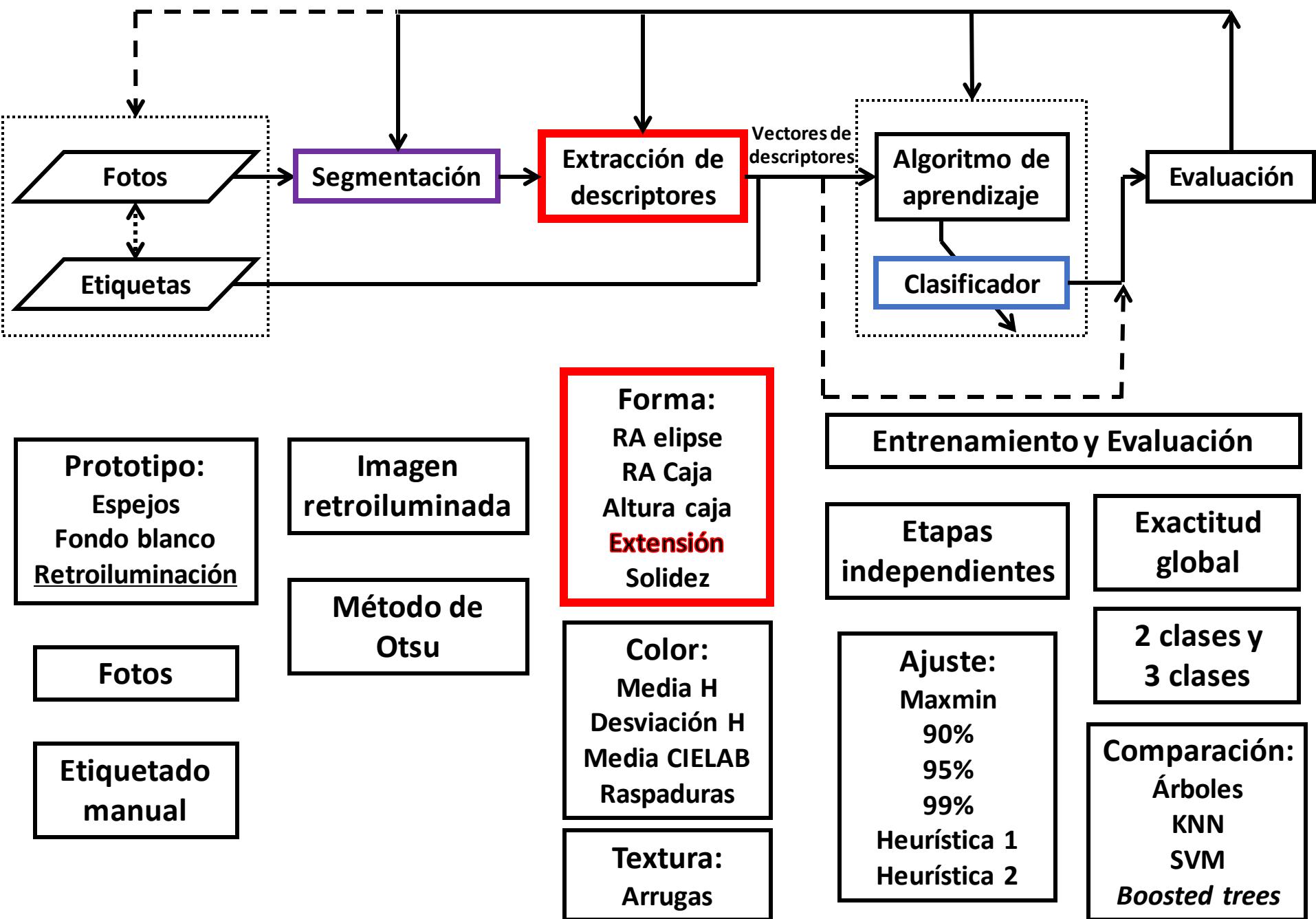
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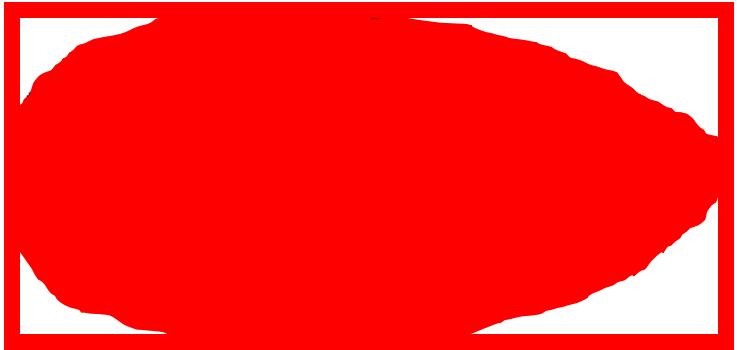






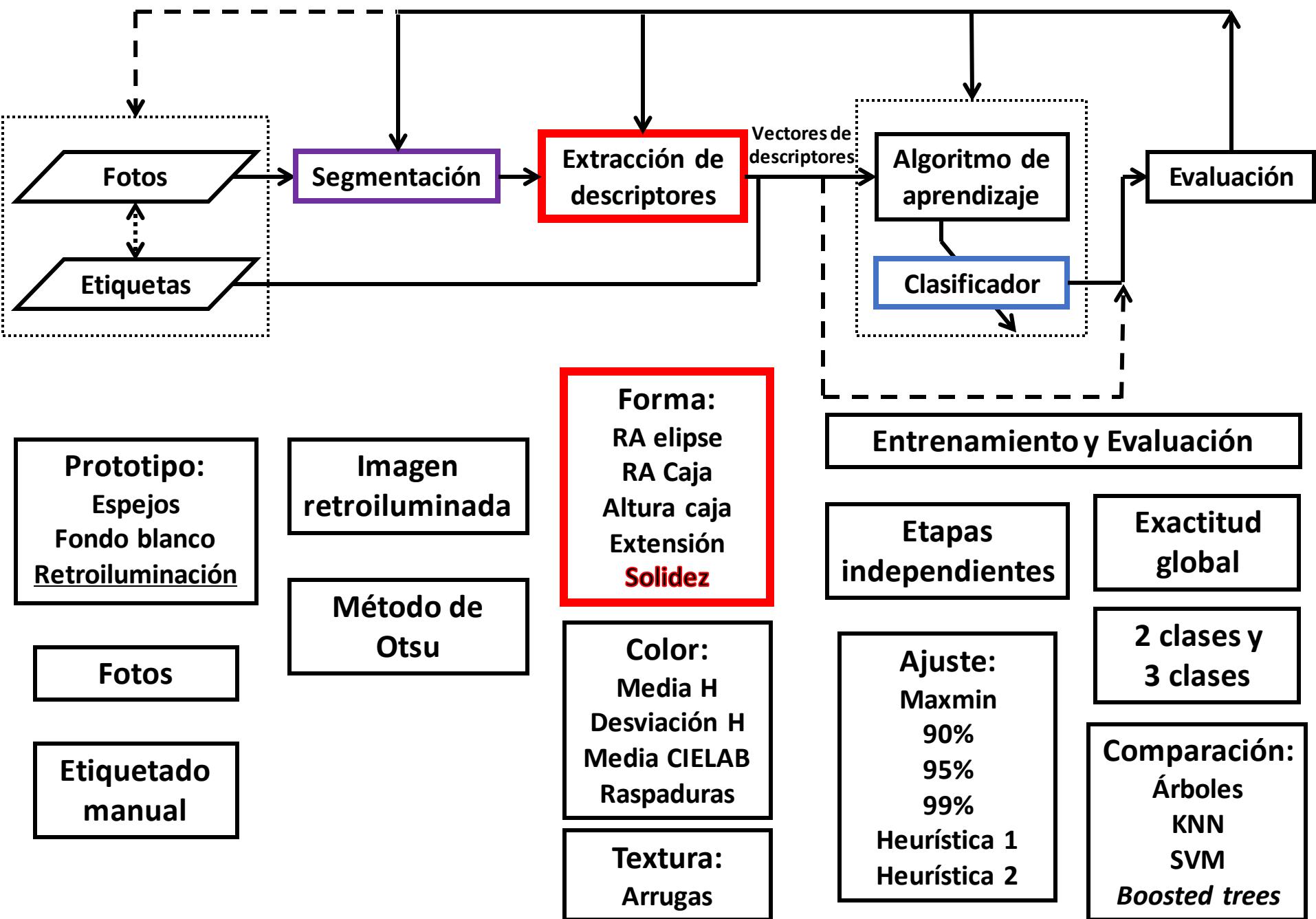
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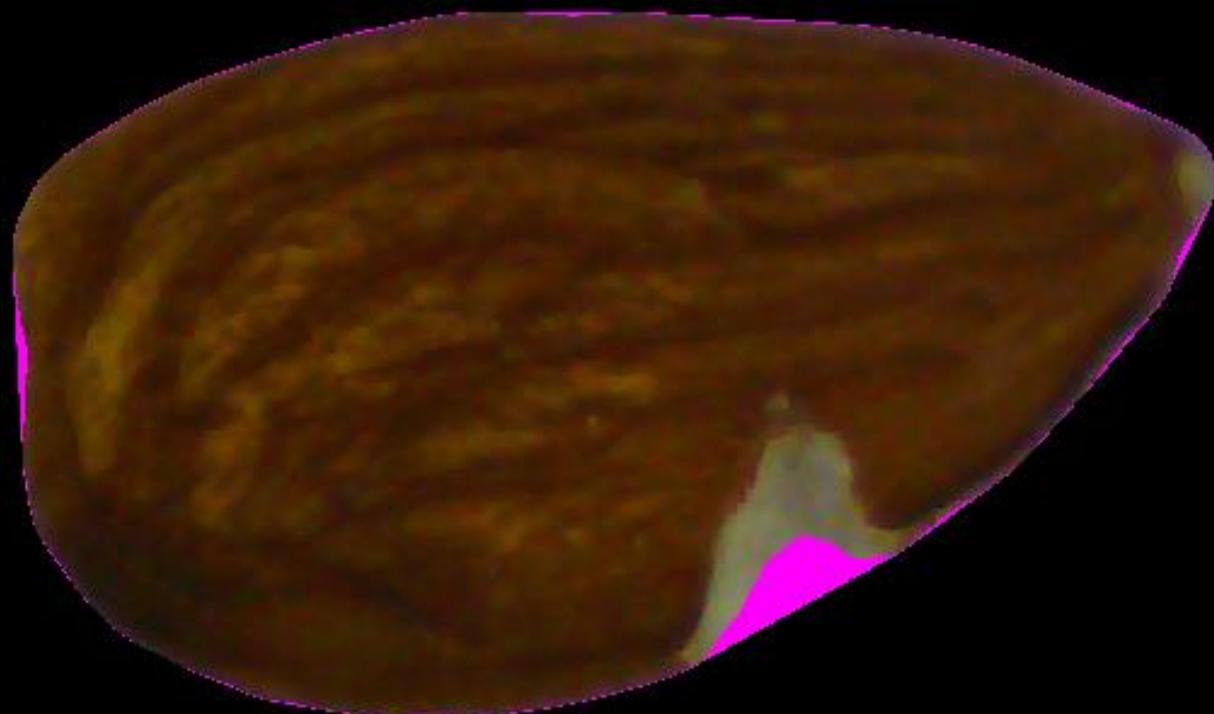


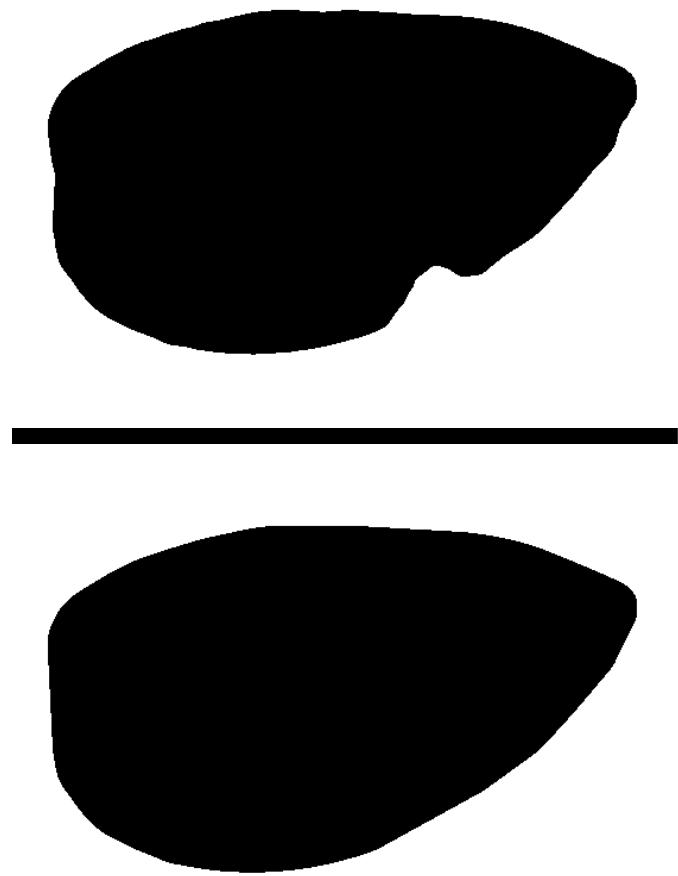
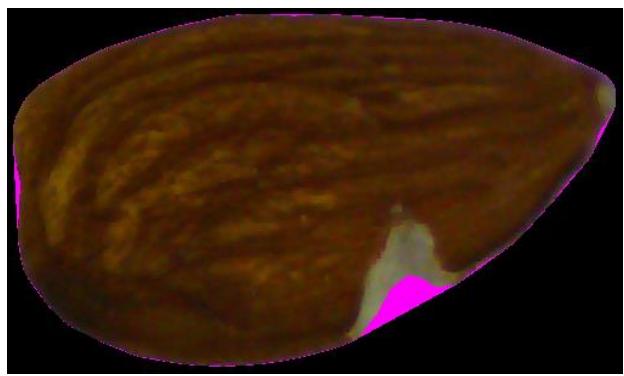


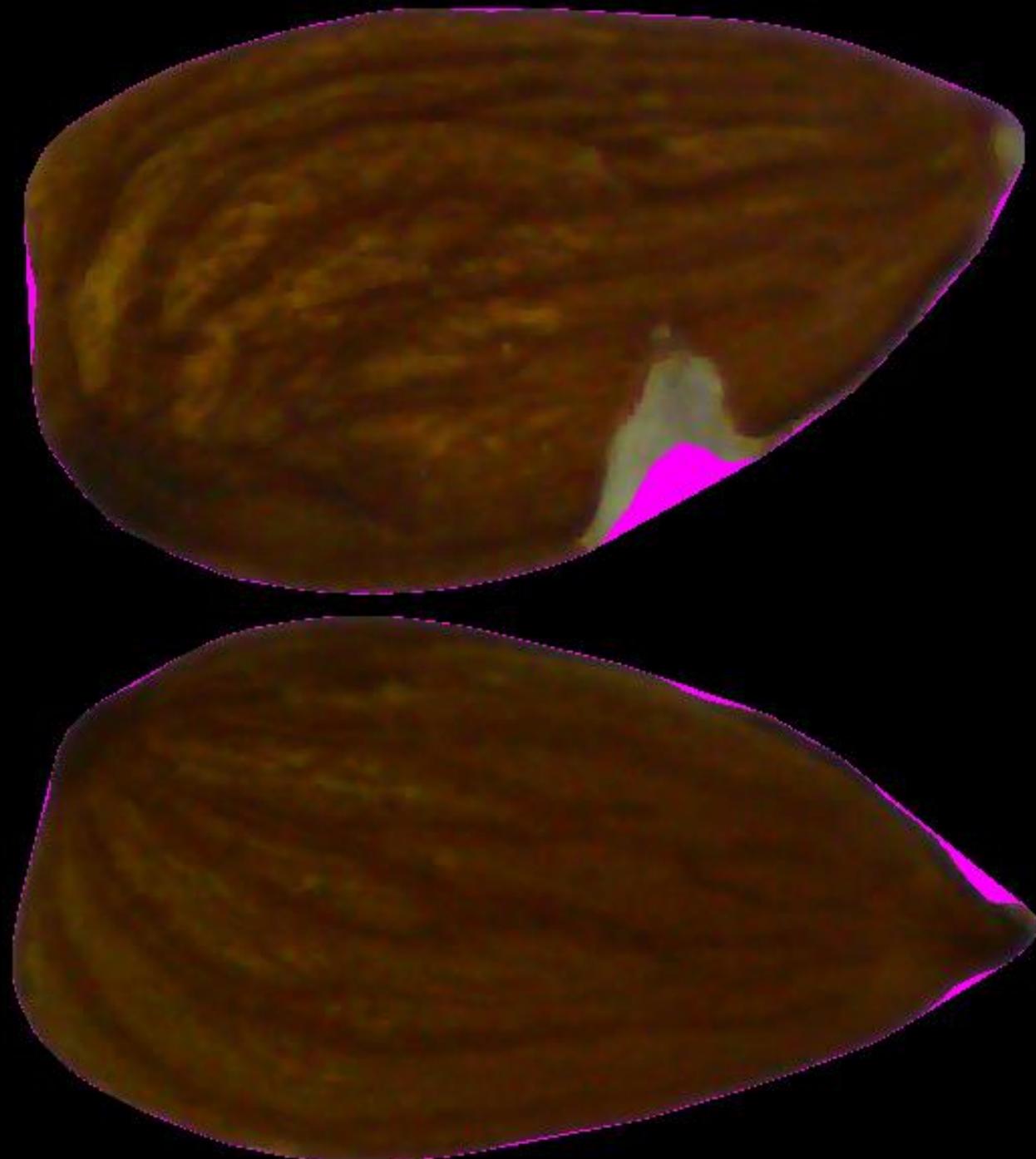
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# Aprendizaje supervisado: entrenamiento

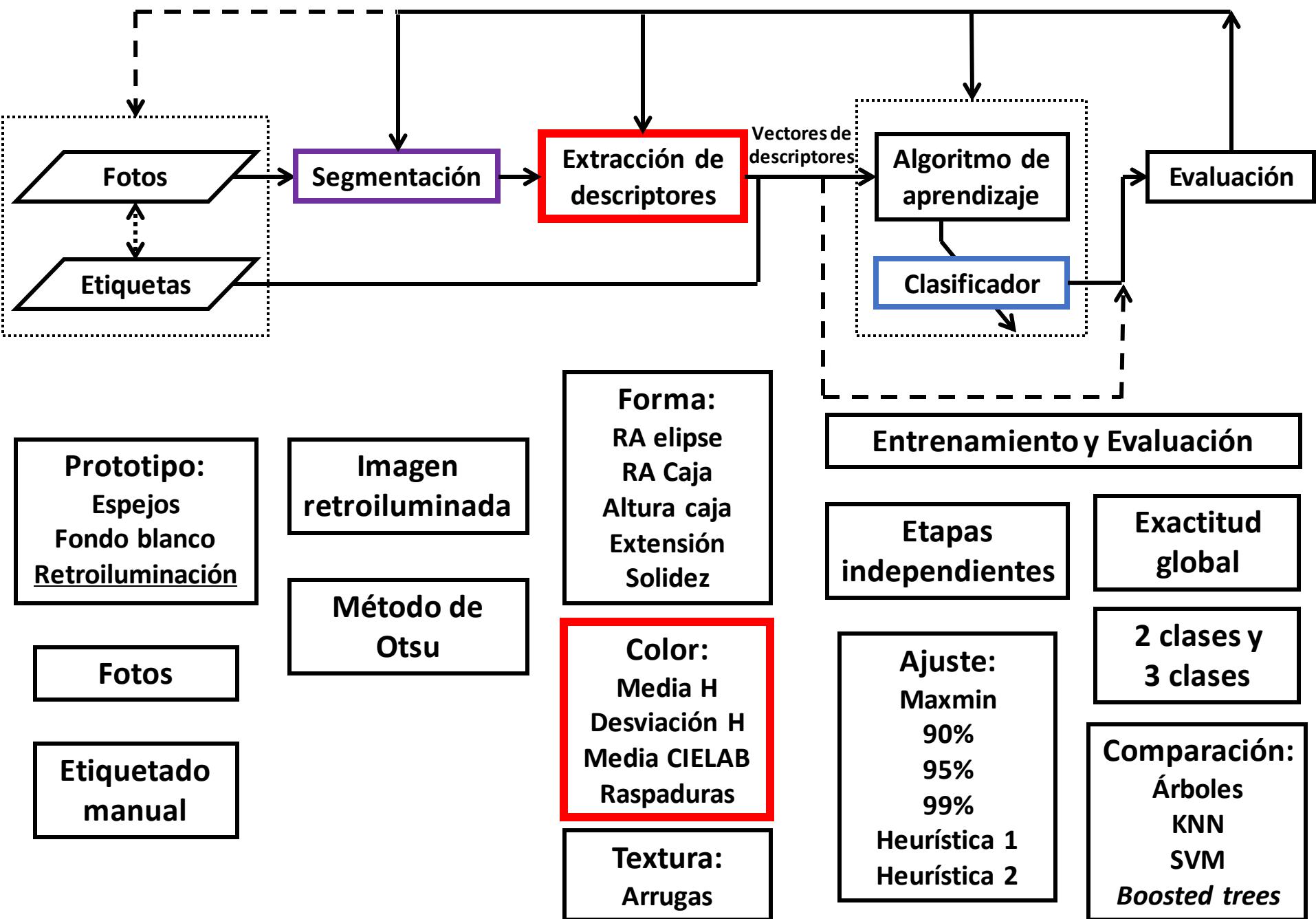




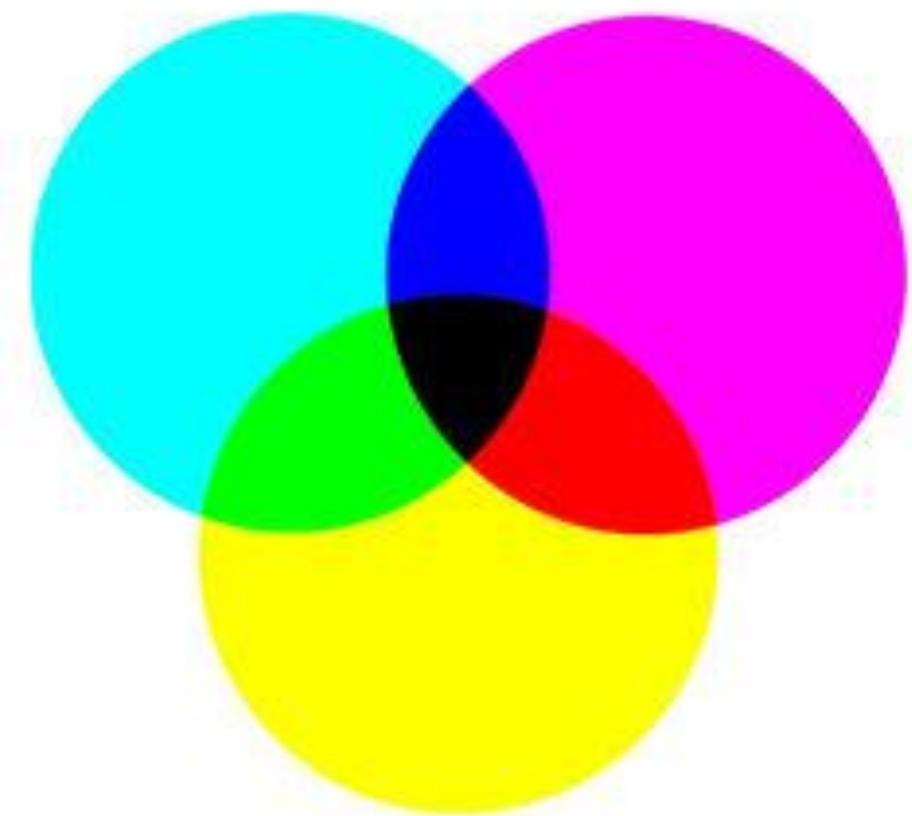




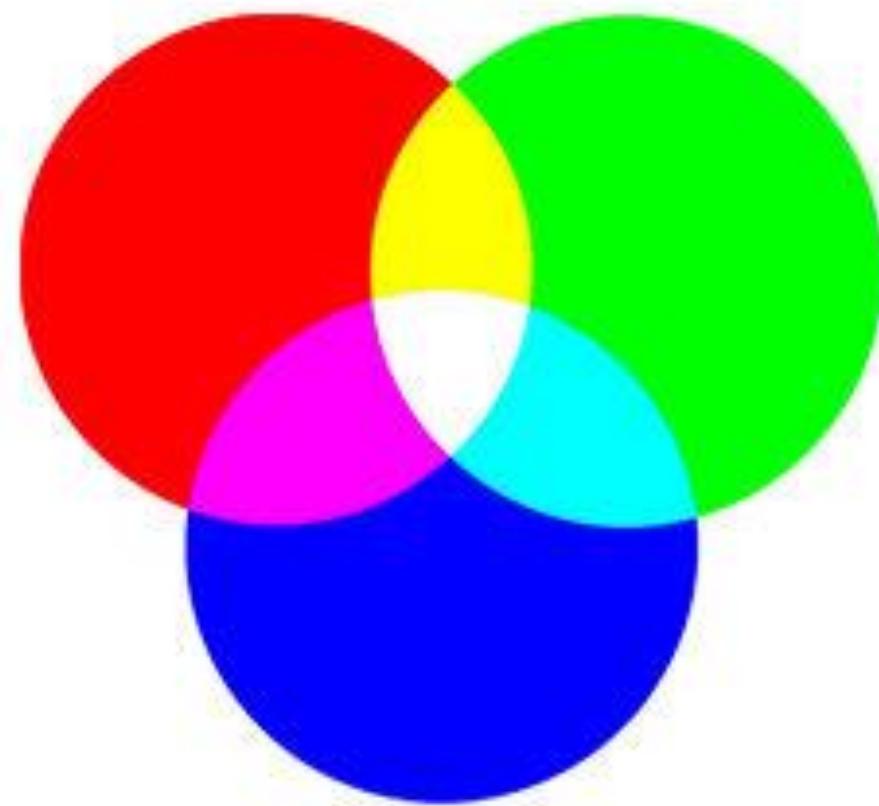
# Aprendizaje supervisado: entrenamiento



**CMY**



**RGB**



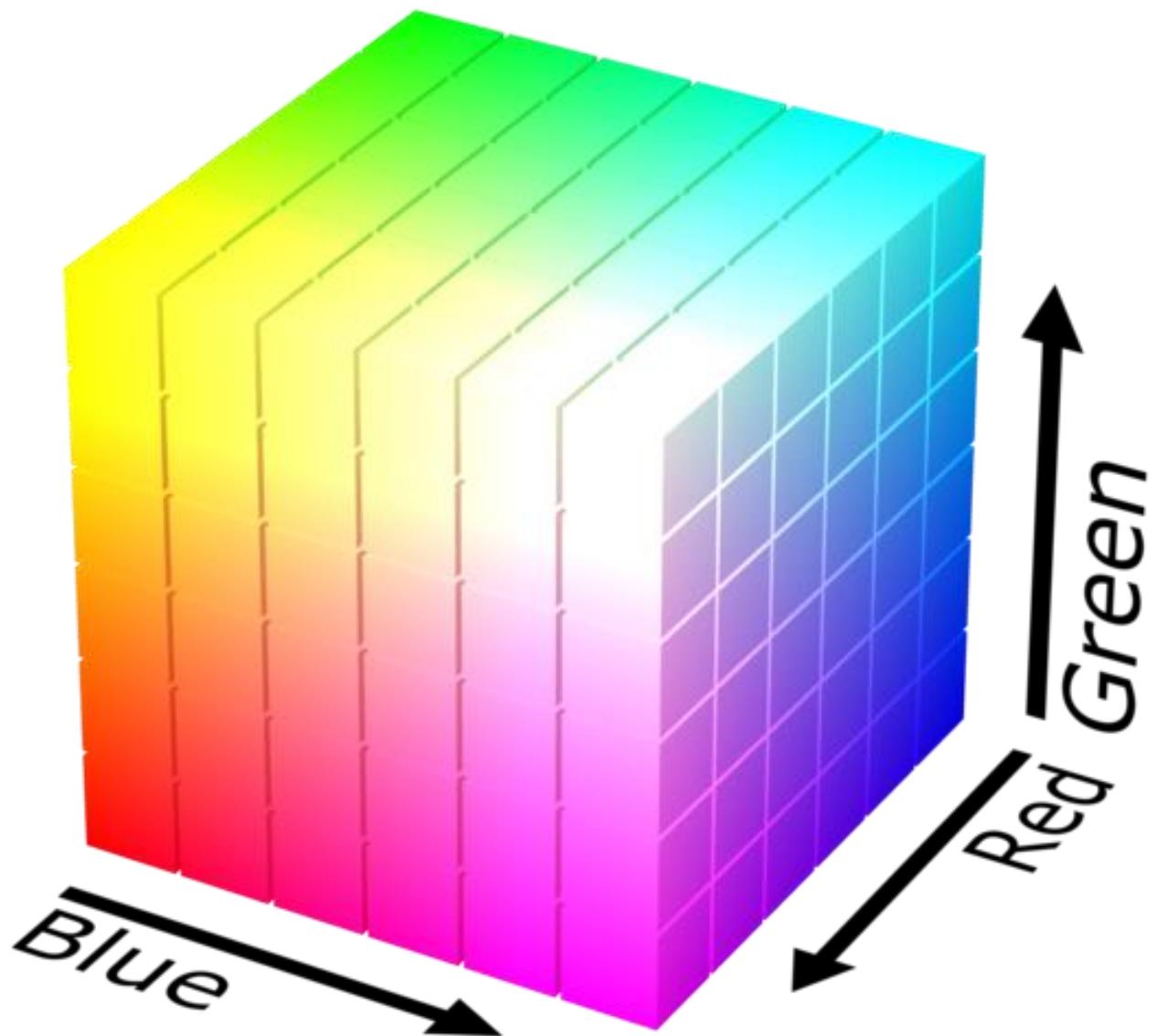


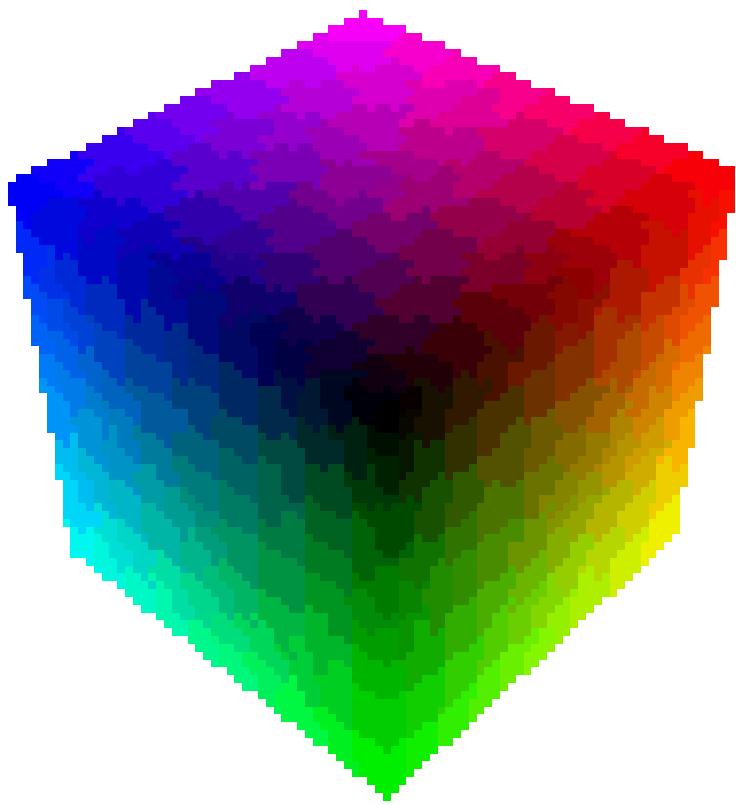
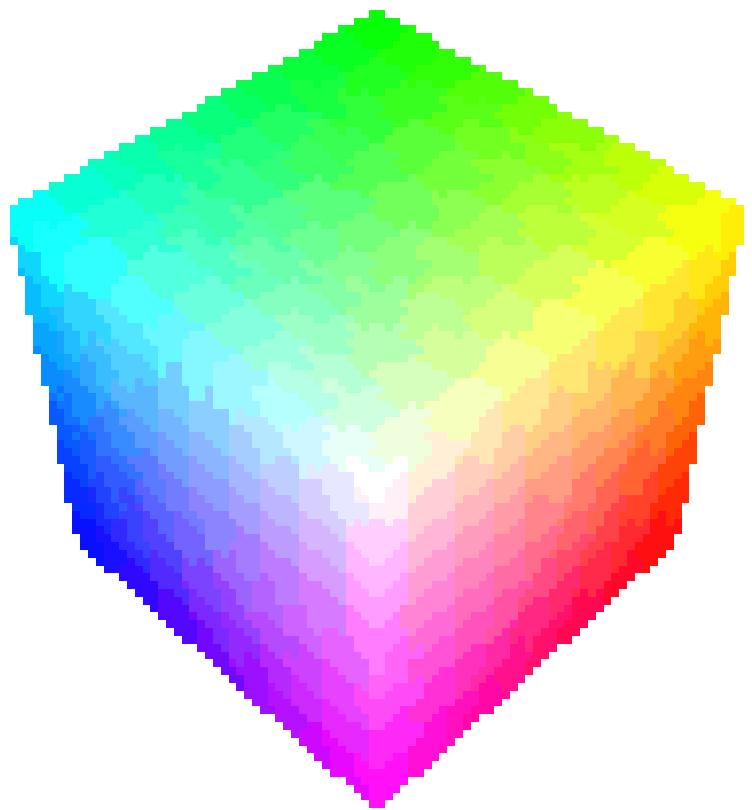




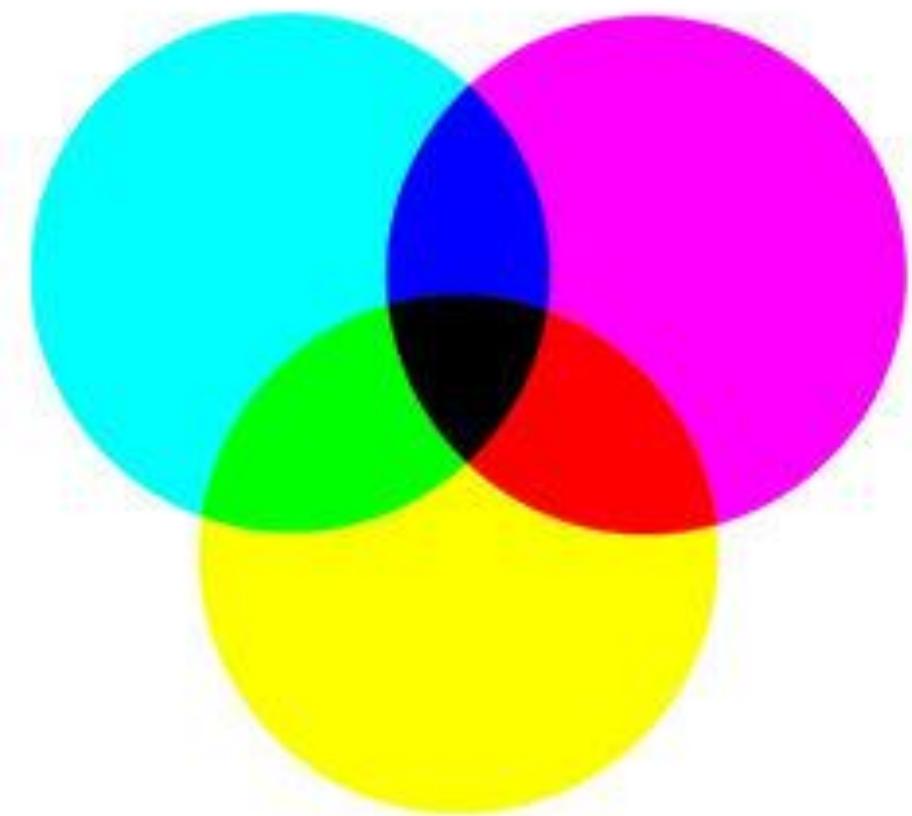




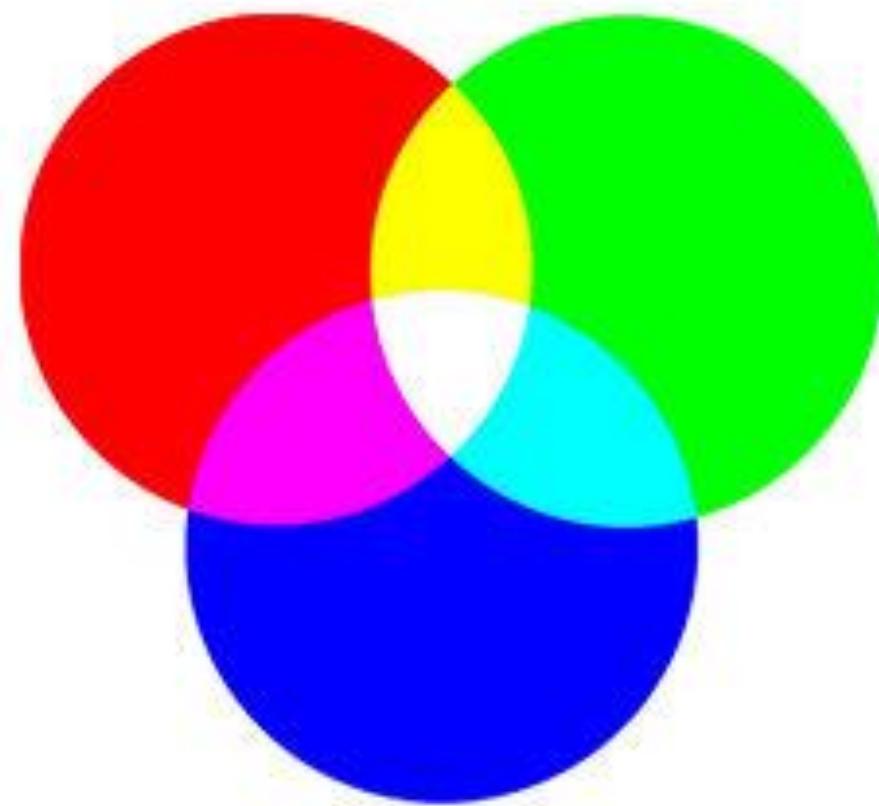




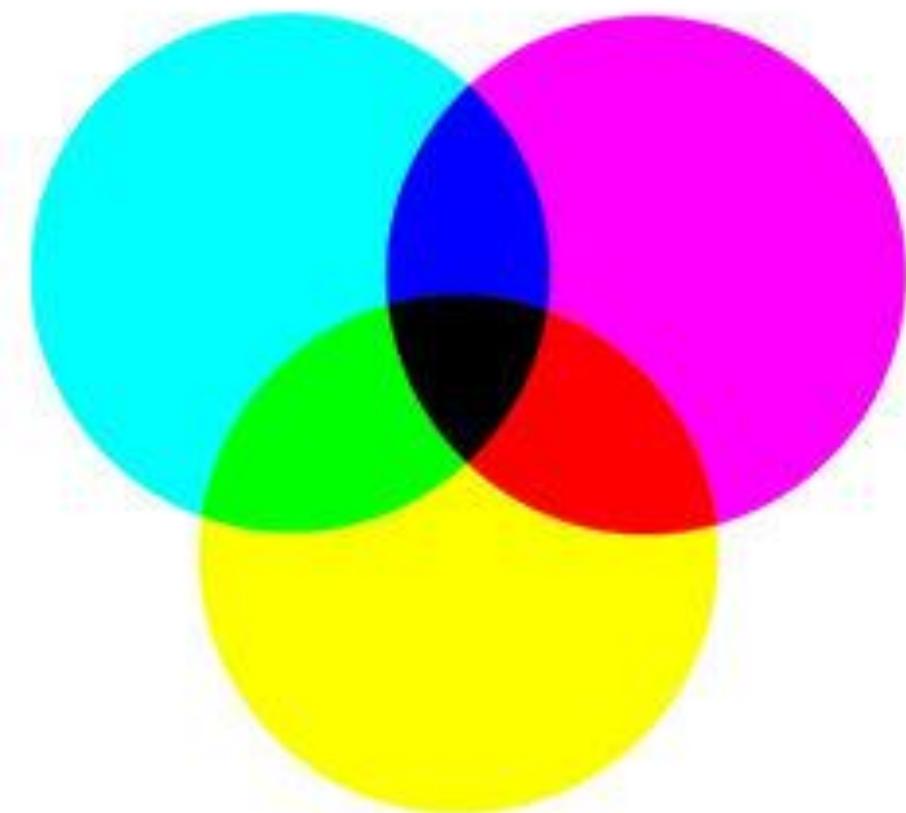
**CMY**



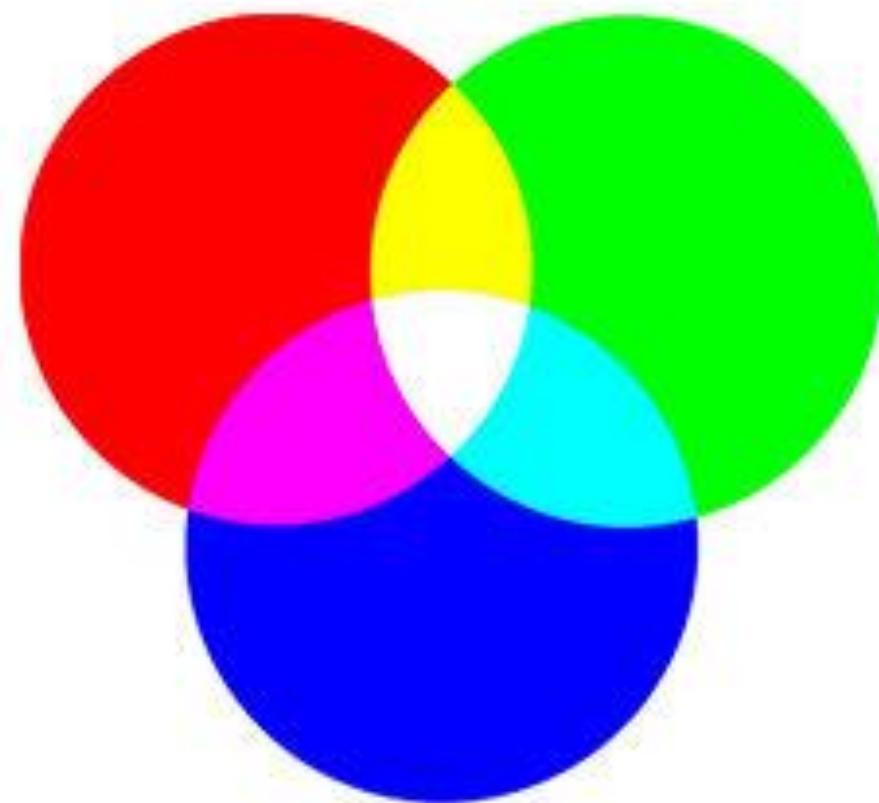
**RGB**



**CMYK**



**RGB**

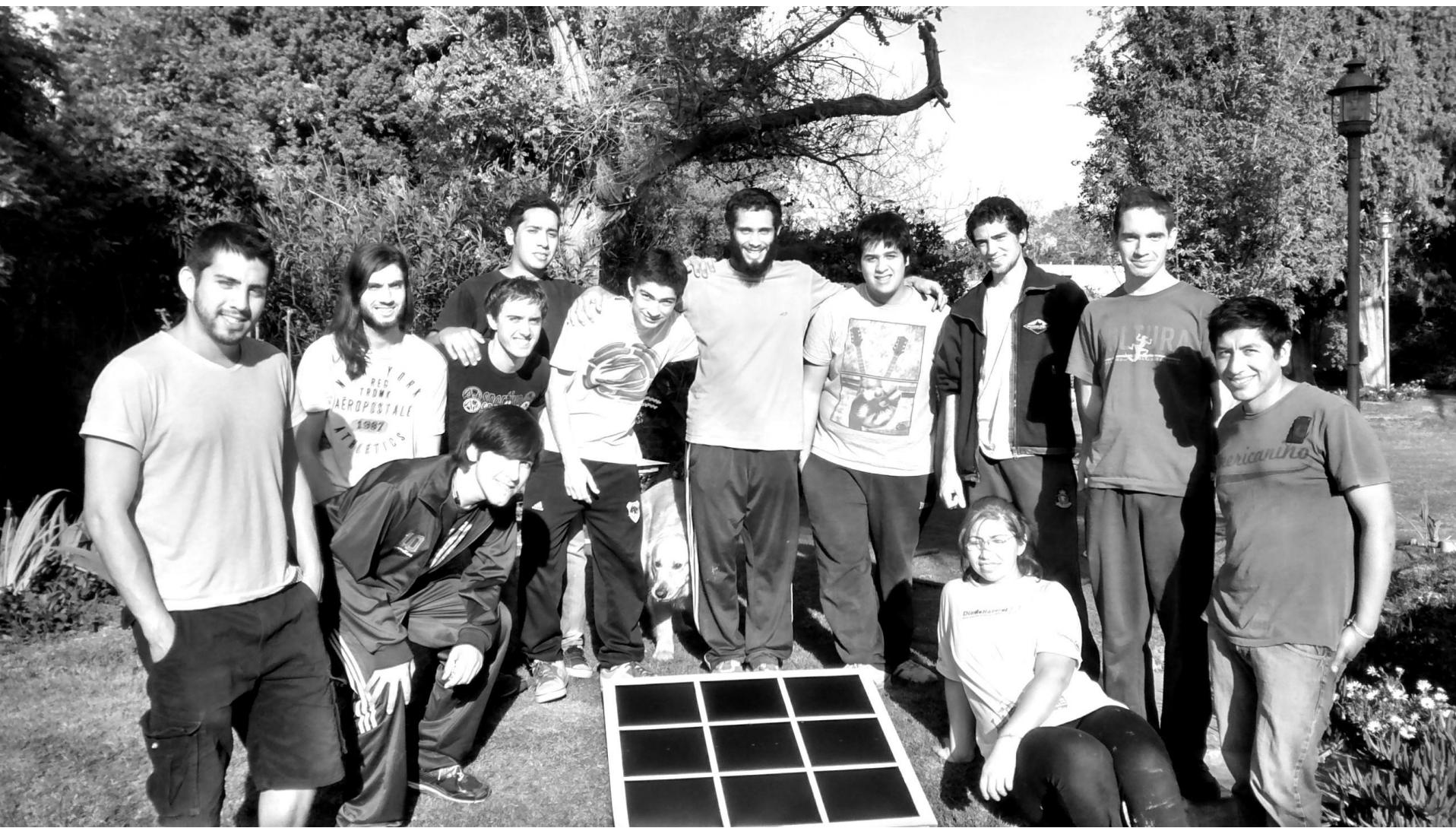


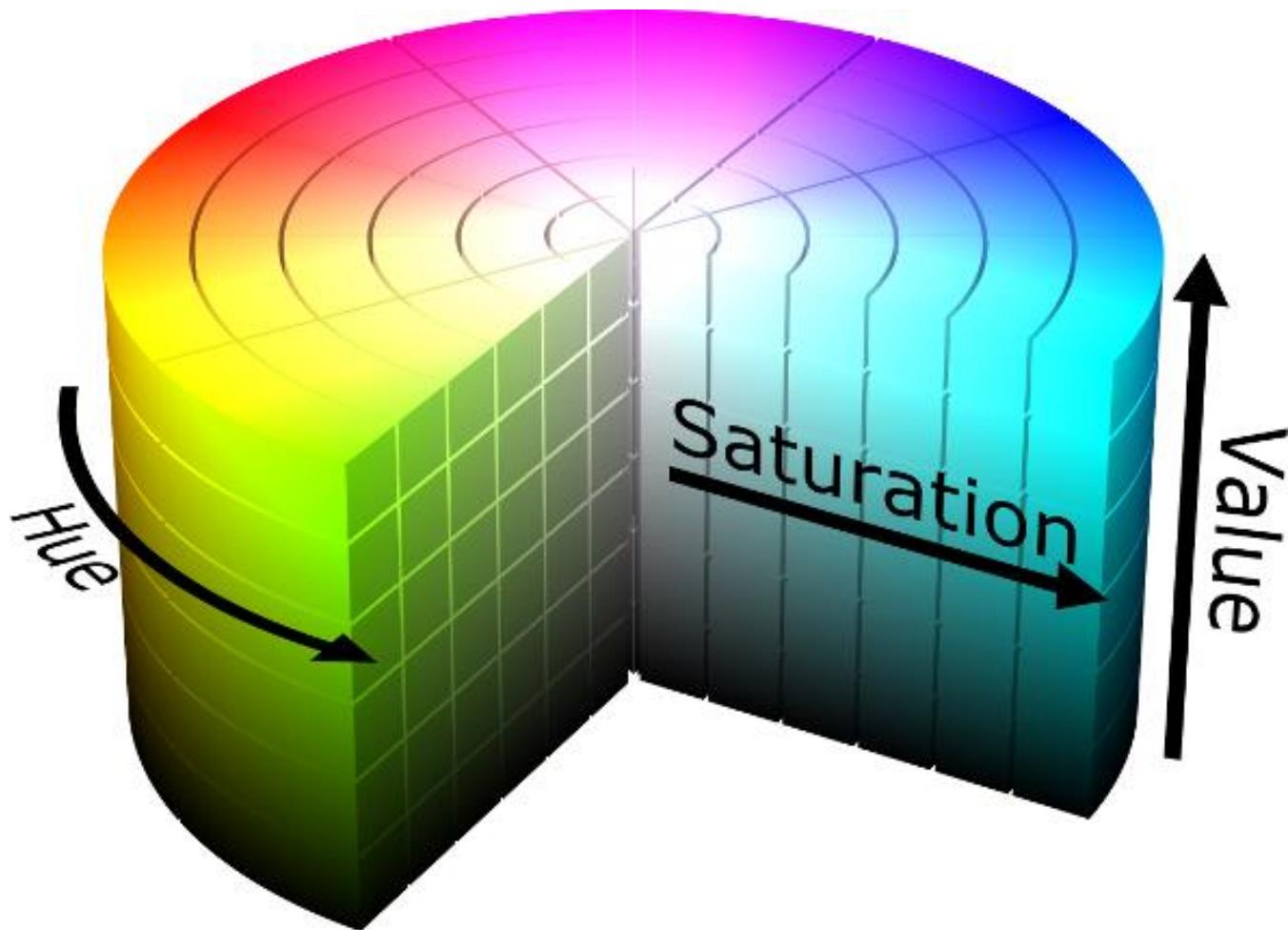




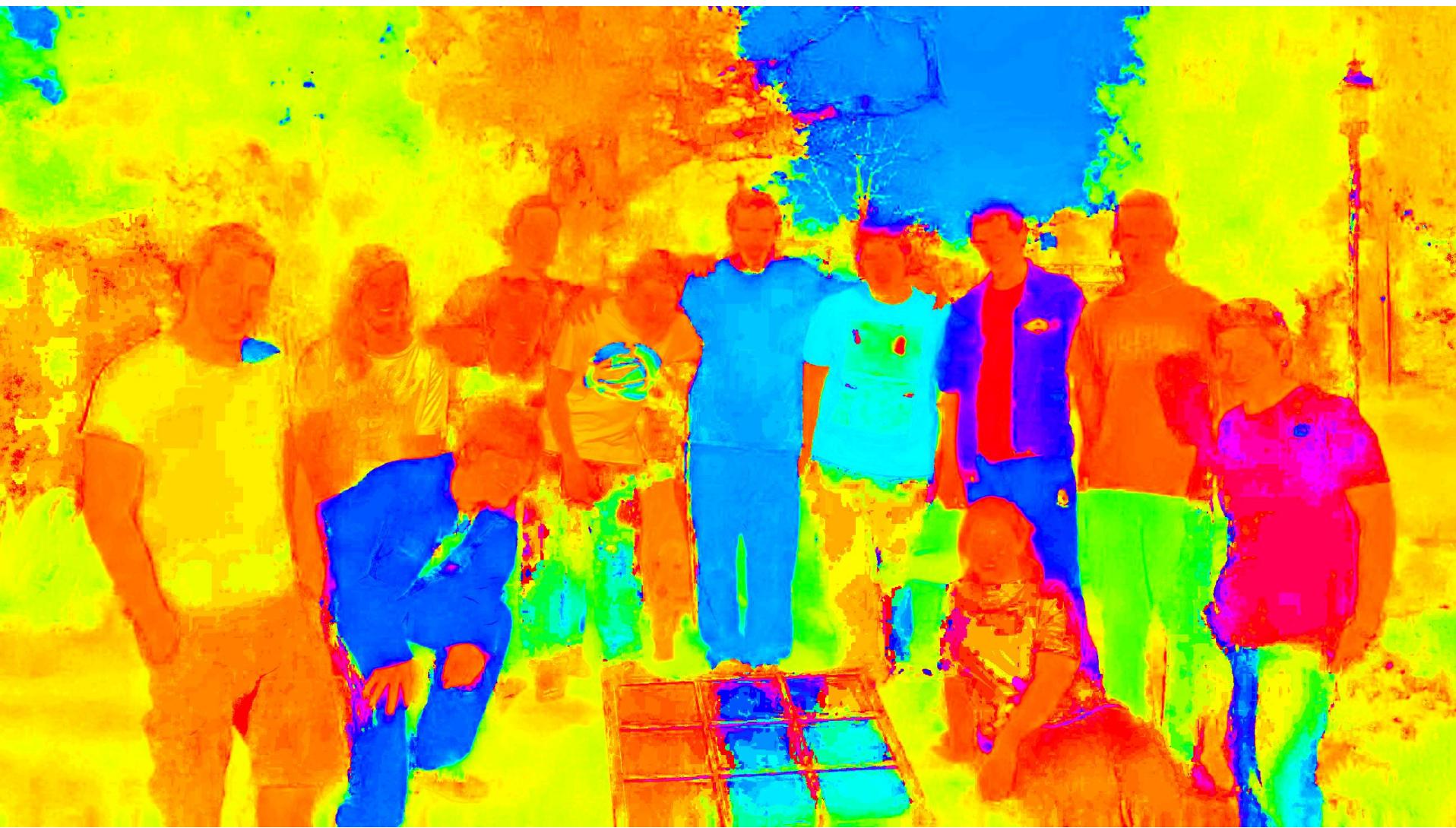






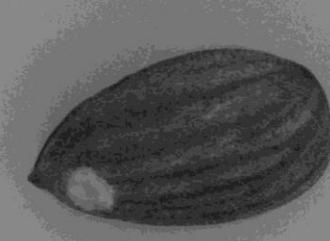
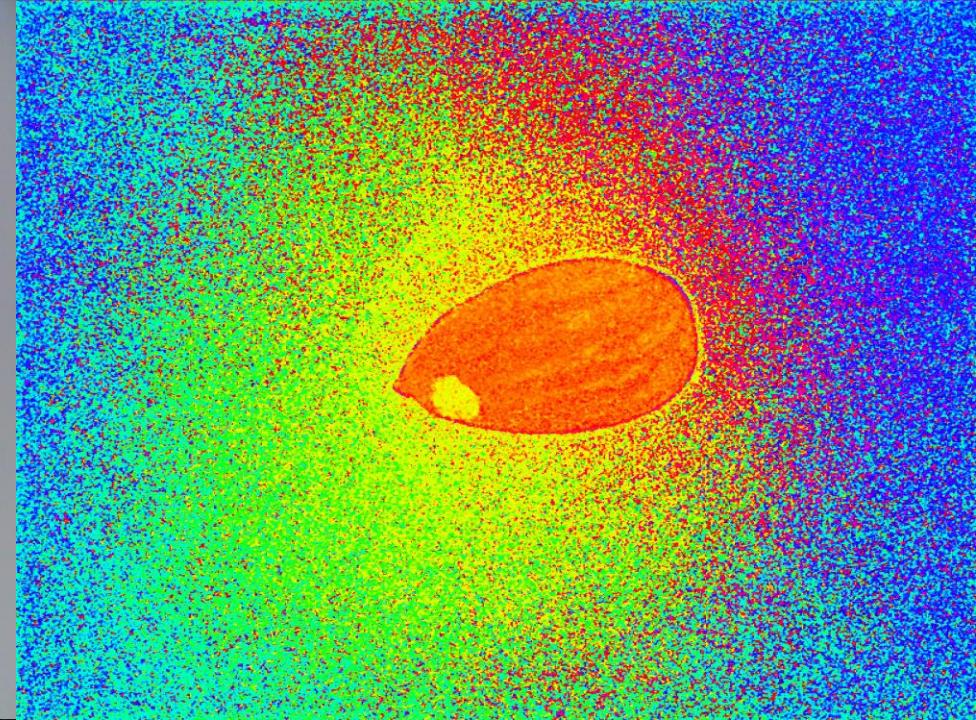


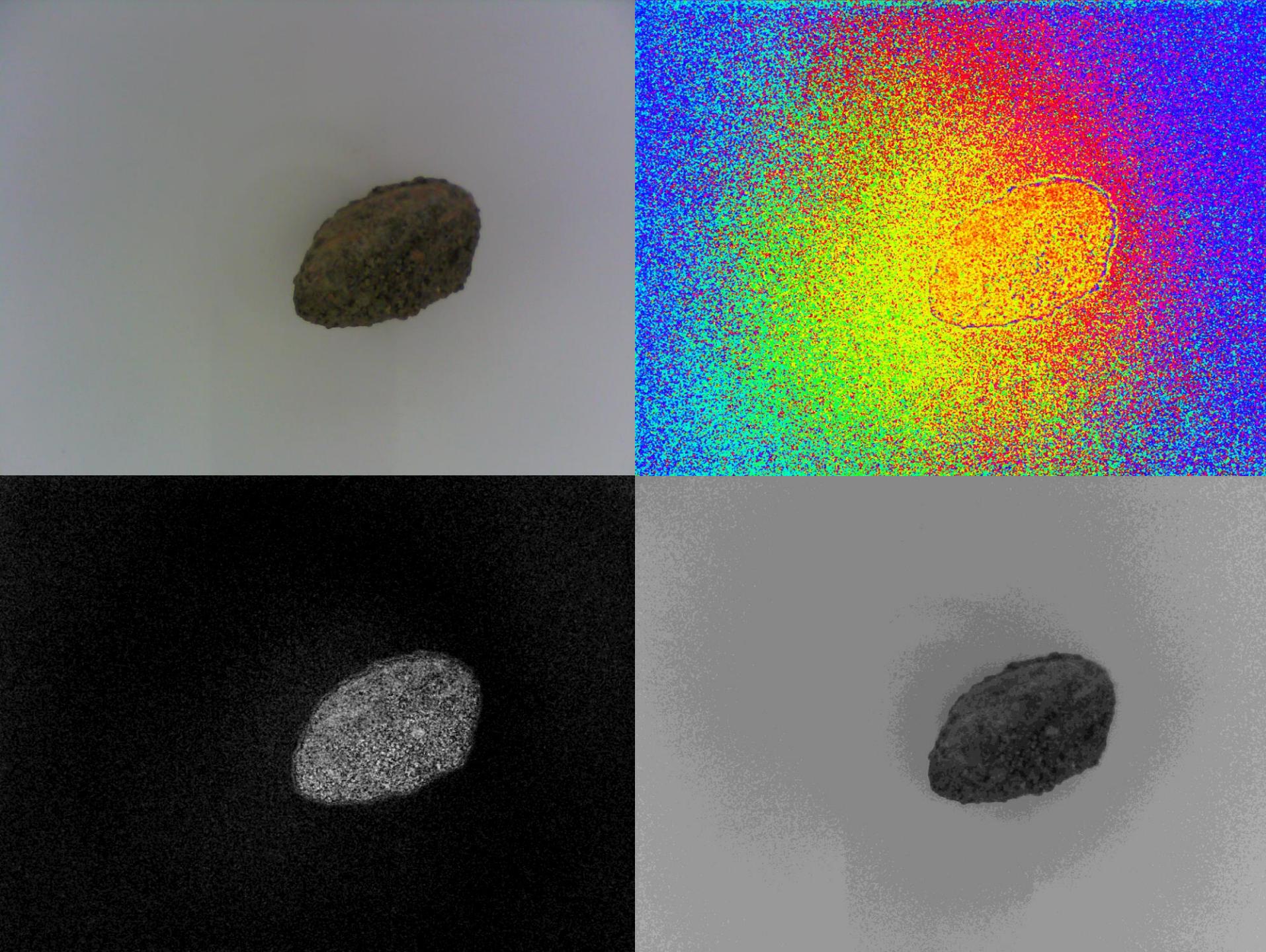


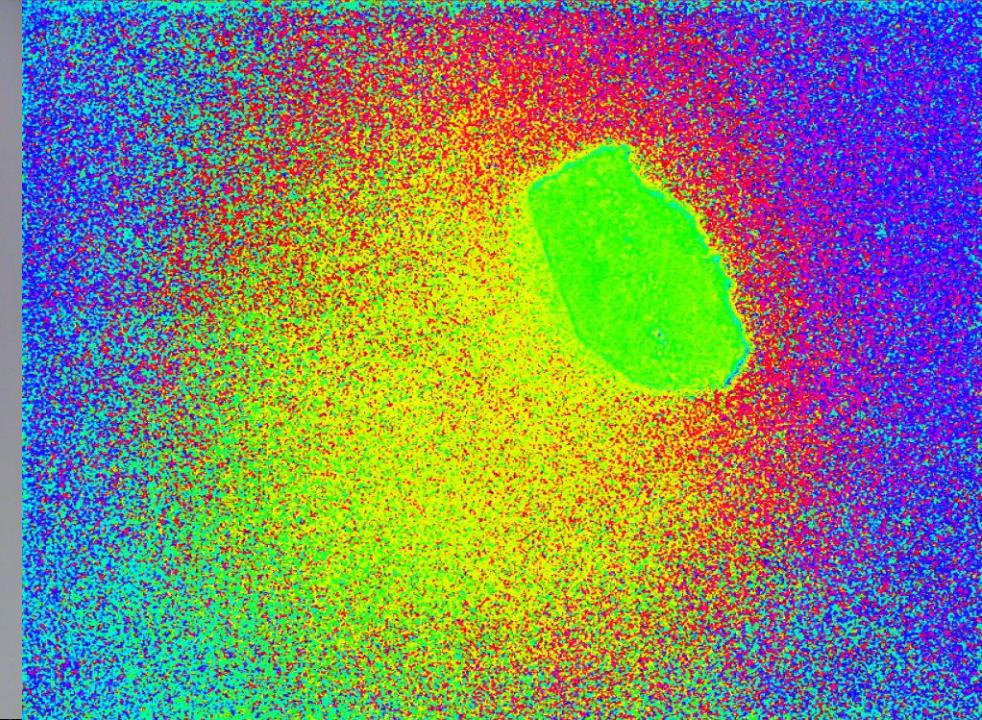




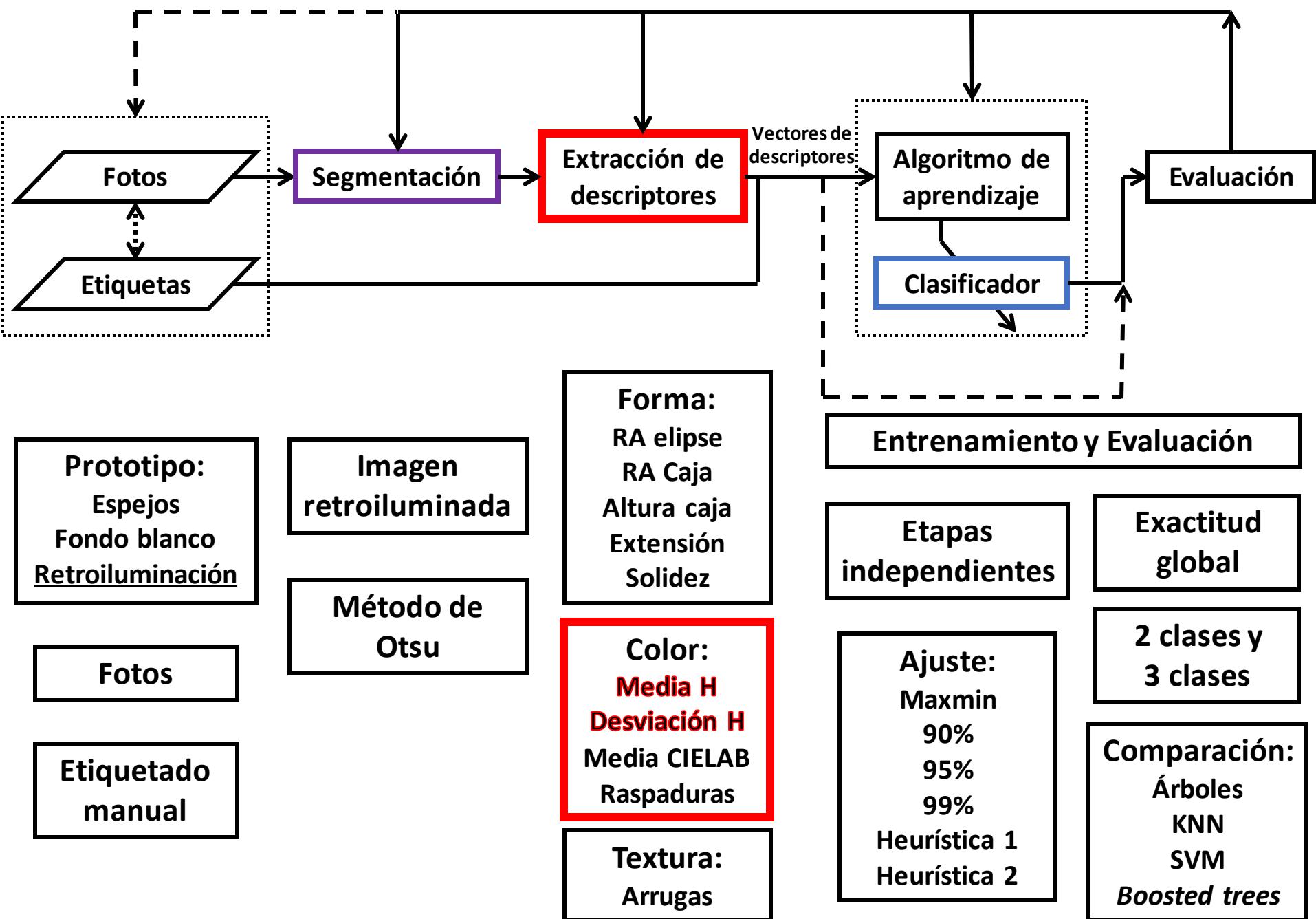


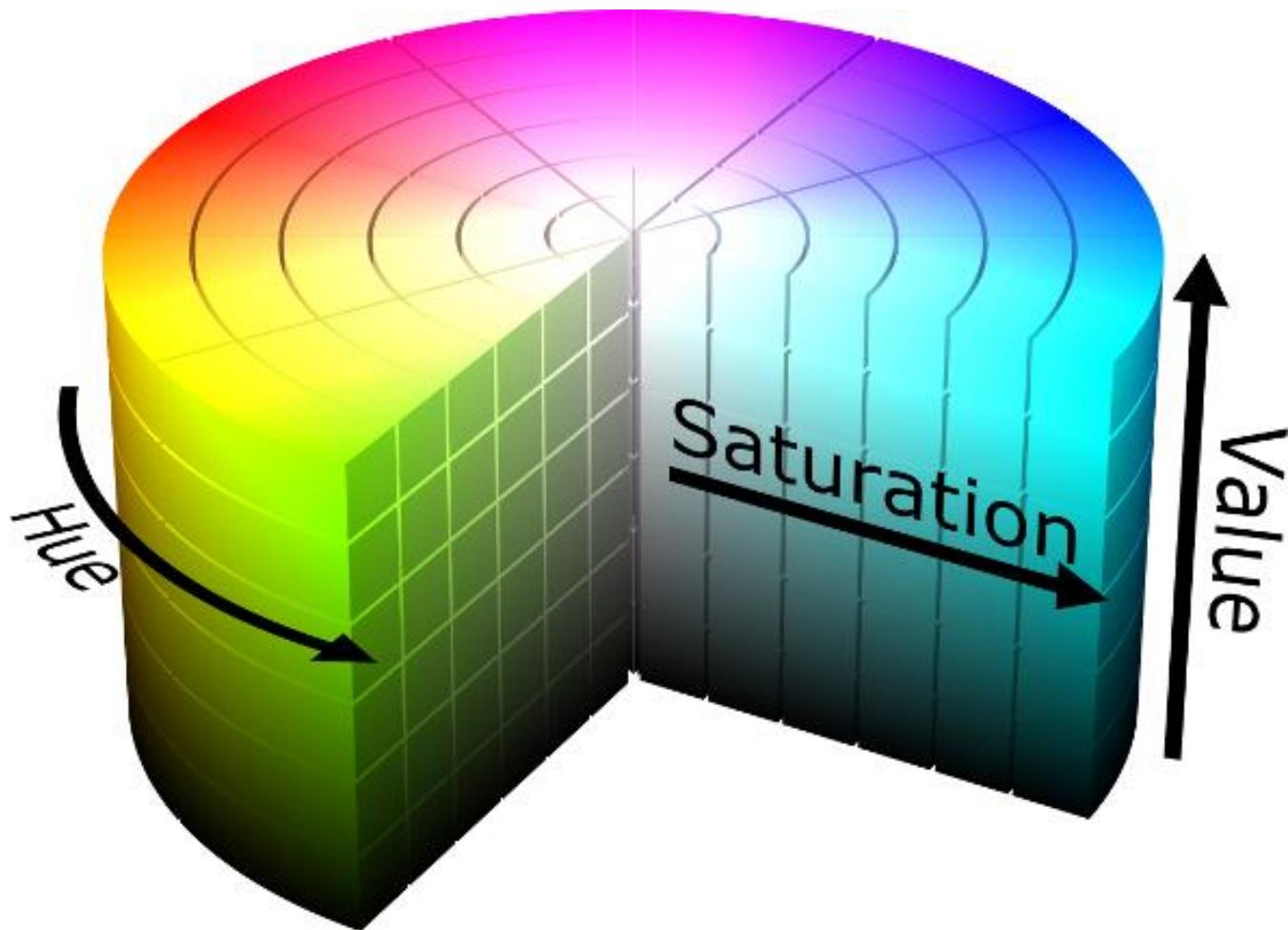


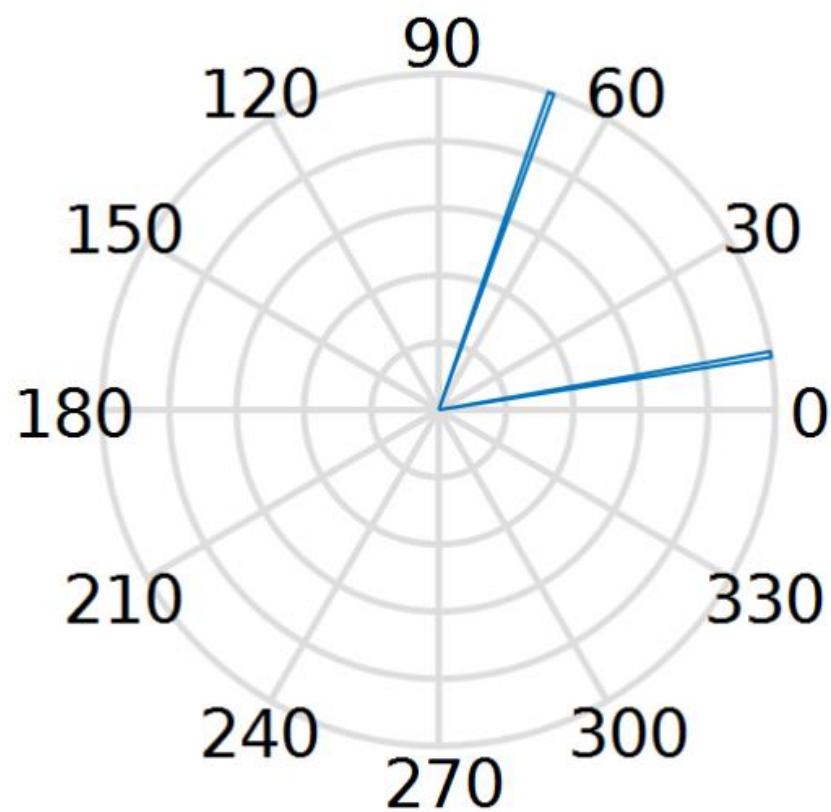
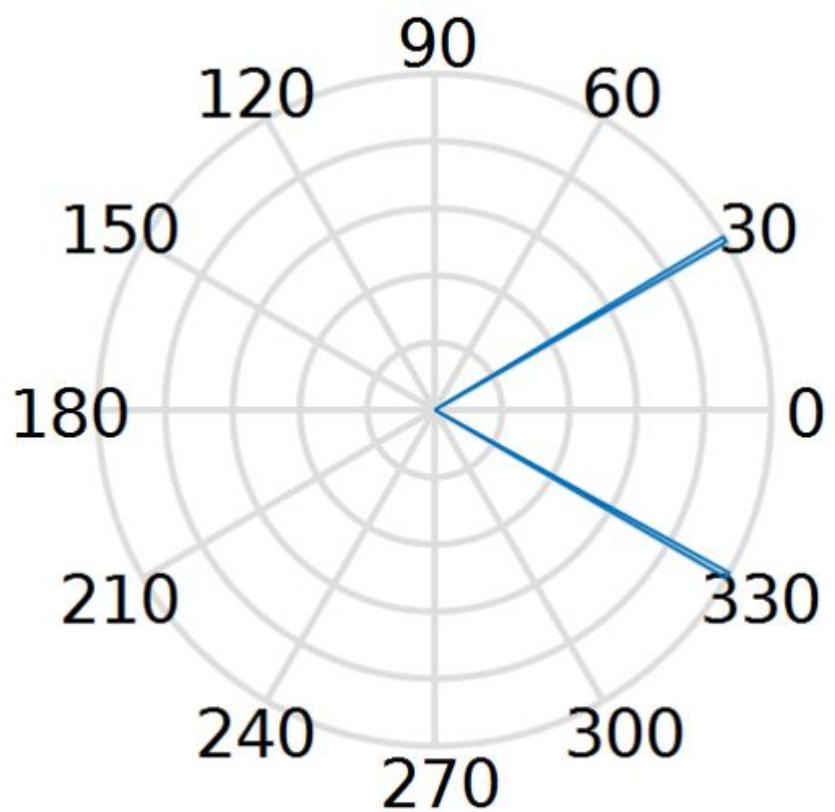


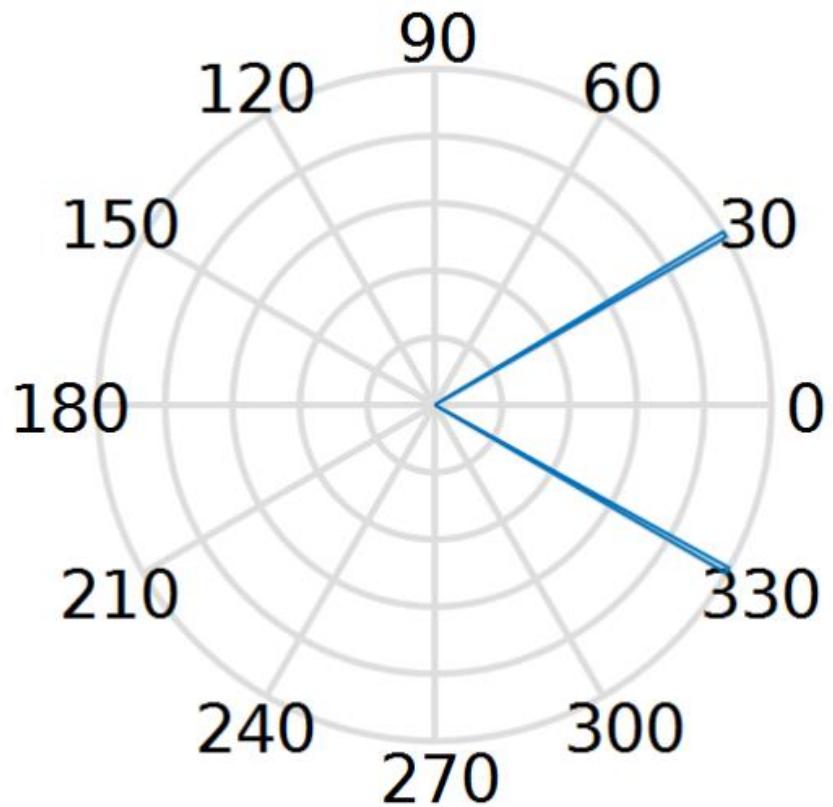


# Aprendizaje supervisado: entrenamiento

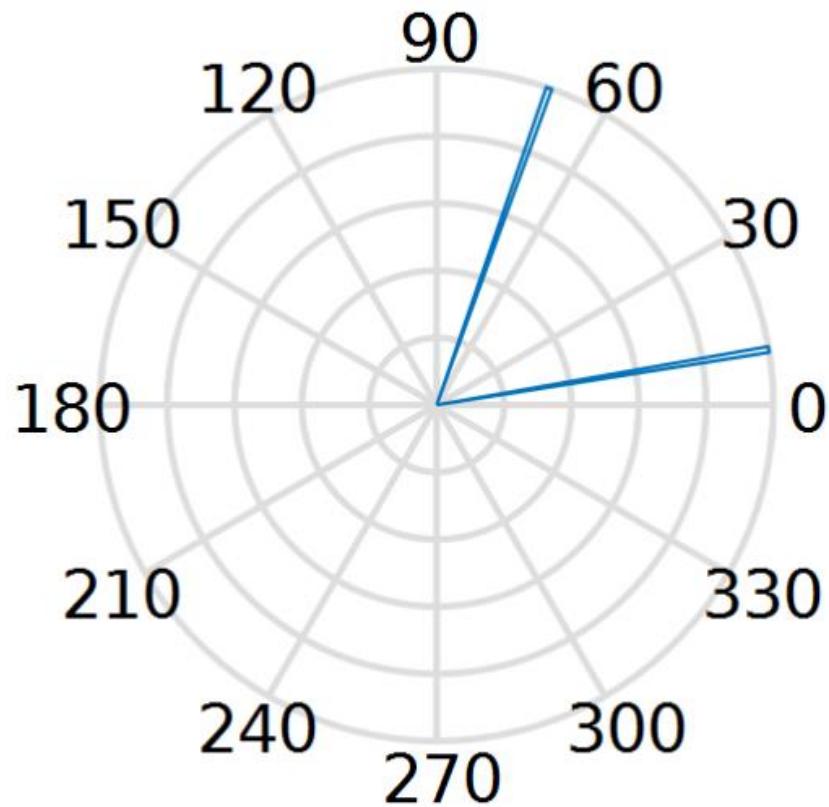




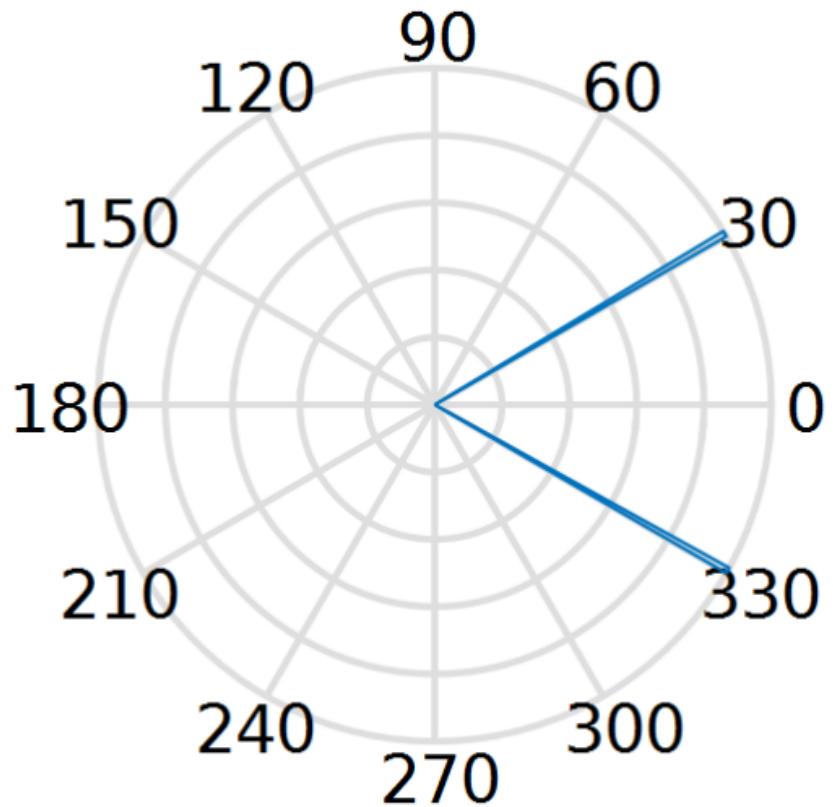




$$\begin{aligned}\mu &= 180^\circ \\ \sigma &= 212, 13^\circ\end{aligned}$$

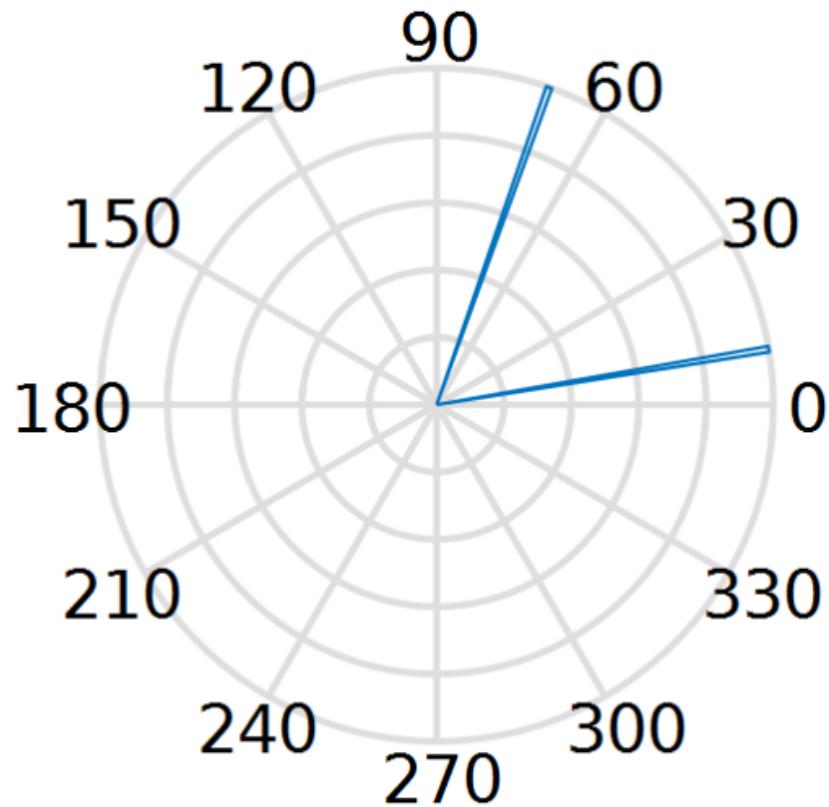


$$\begin{aligned}\mu &= 40^\circ \\ \sigma &= 42, 42^\circ\end{aligned}$$



$$\begin{aligned}\mu &= 180^\circ \\ \sigma &= 212, 13^\circ\end{aligned}$$

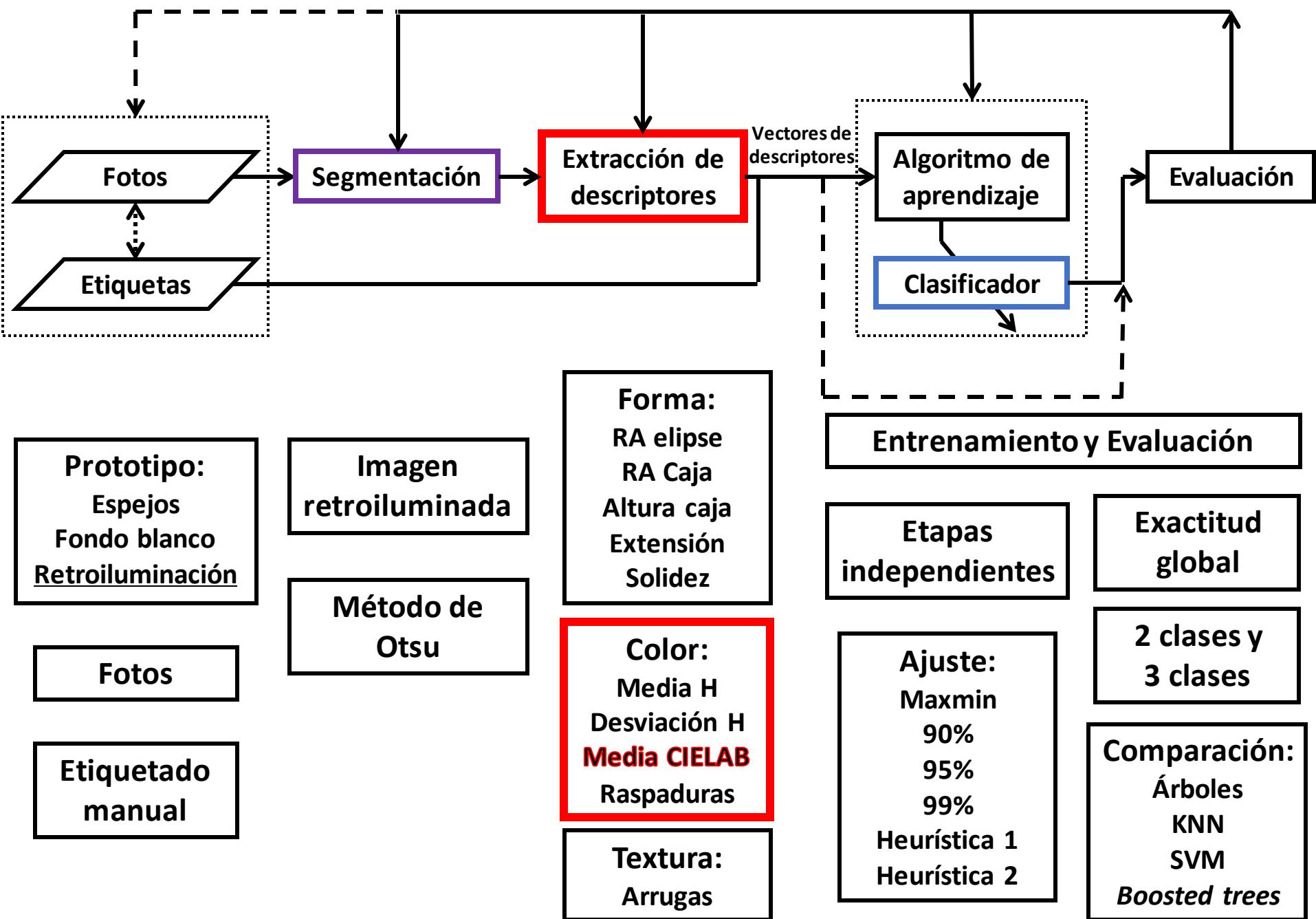
$$\begin{aligned}\rho &= 0^\circ \\ S &= 30, 73^\circ\end{aligned}$$

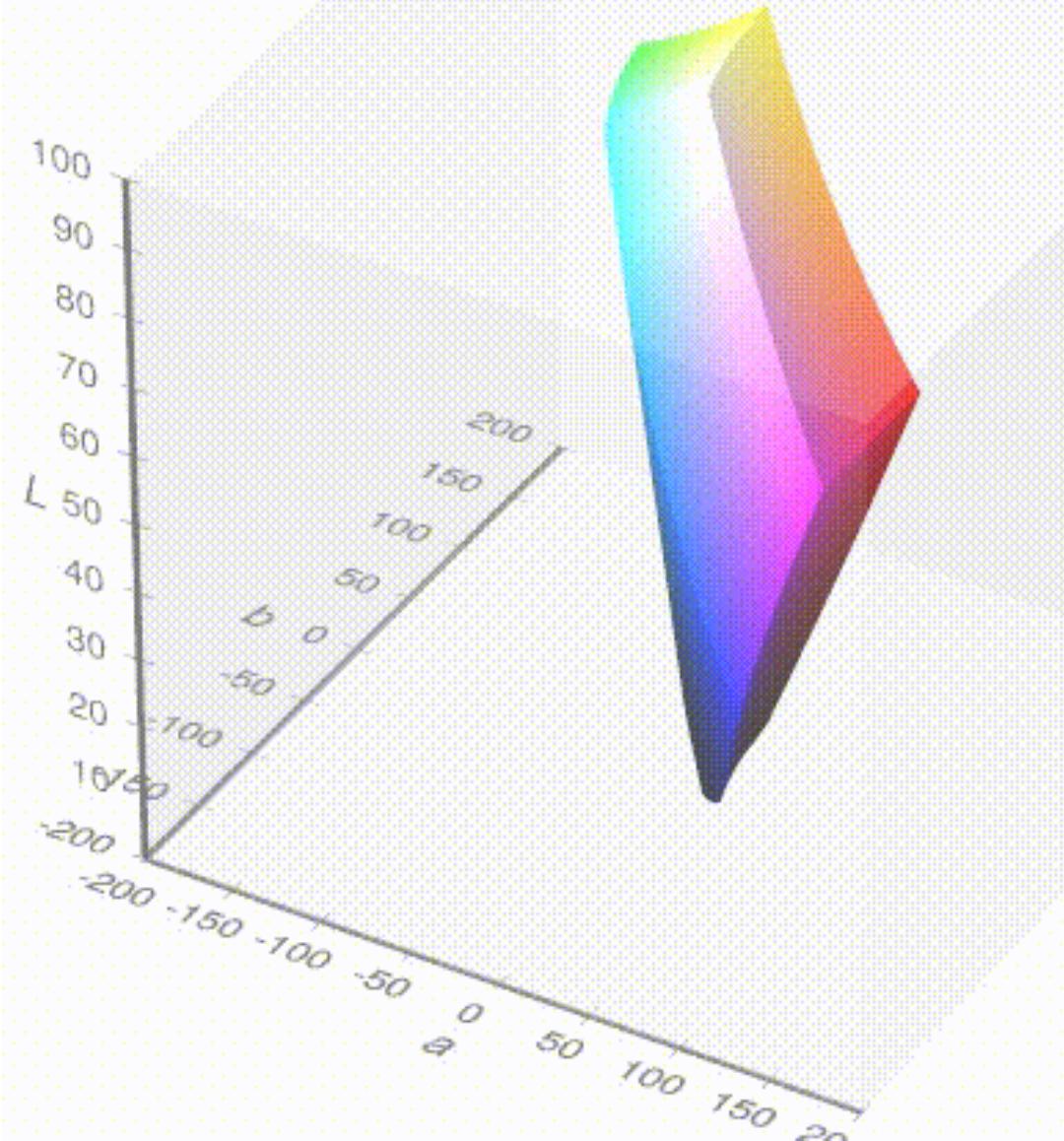


$$\begin{aligned}\mu &= 40^\circ \\ \sigma &= 42, 42^\circ\end{aligned}$$

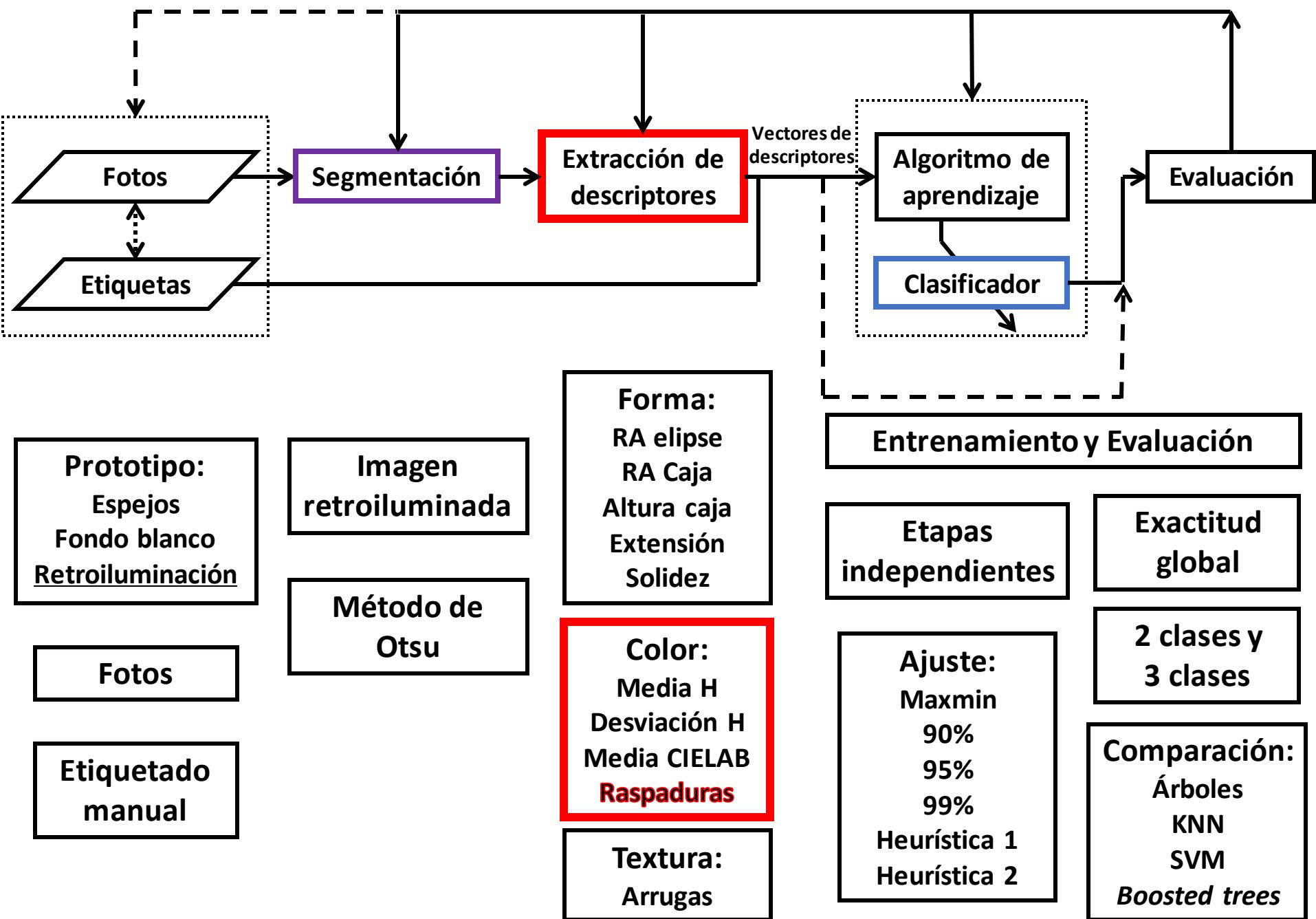
$$\begin{aligned}\rho &= 40^\circ \\ S &= 30, 73^\circ\end{aligned}$$

# Aprendizaje supervisado: entrenamiento

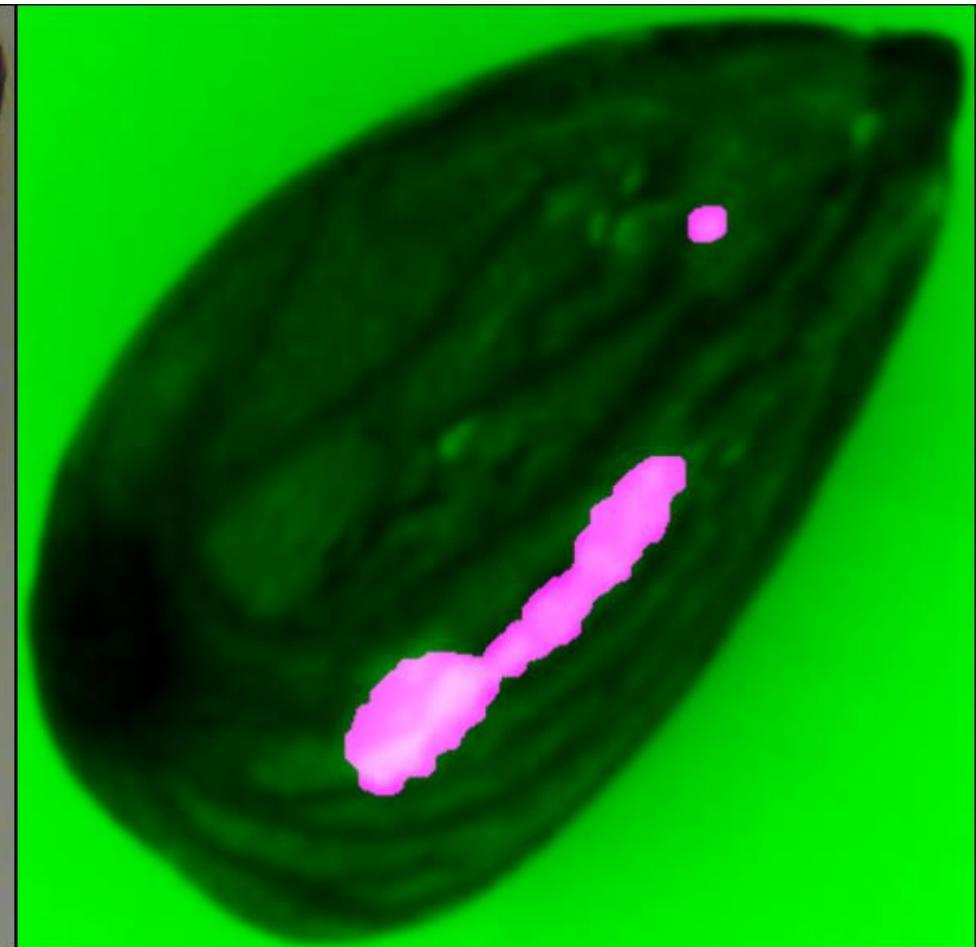




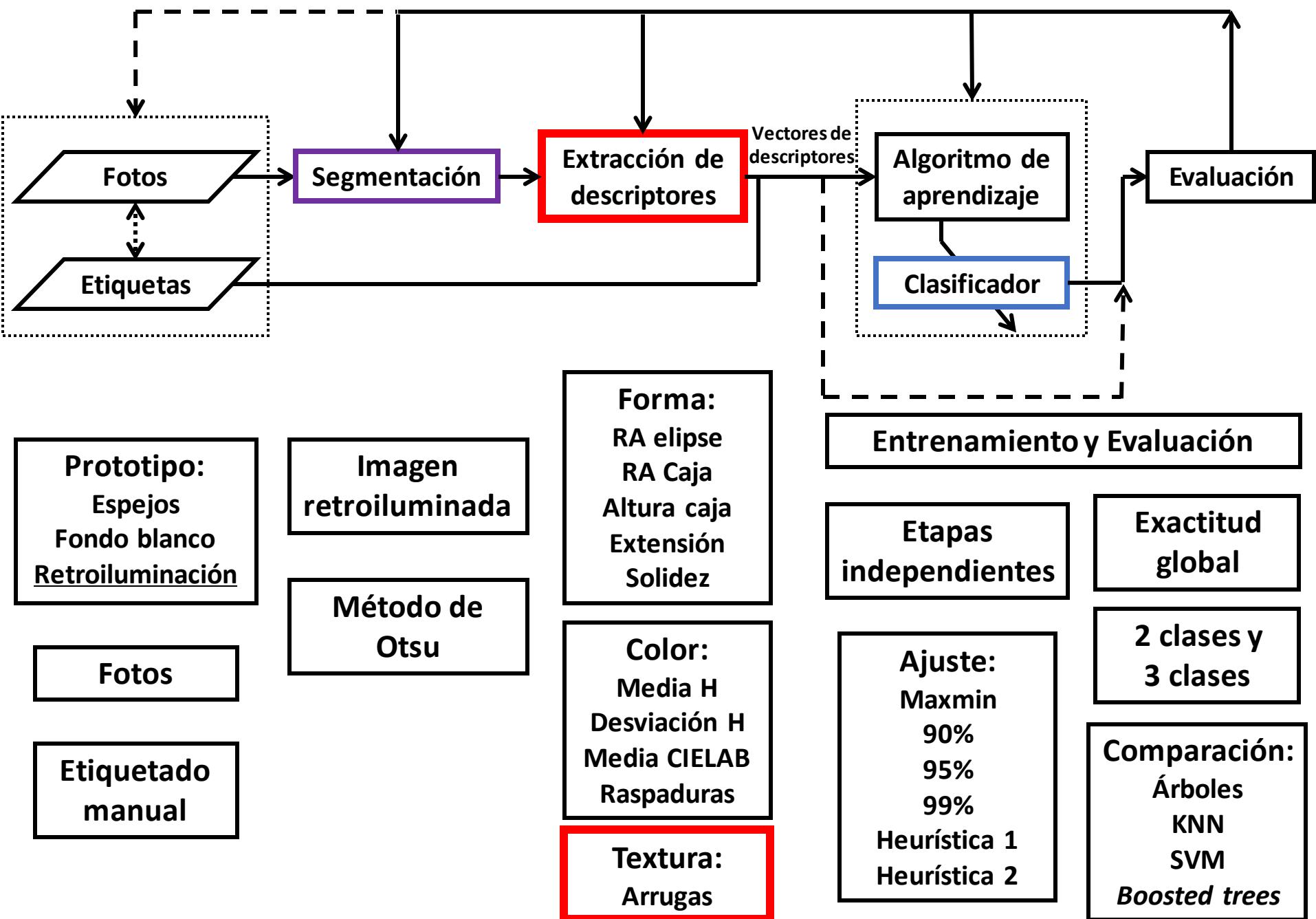
# Aprendizaje supervisado: entrenamiento

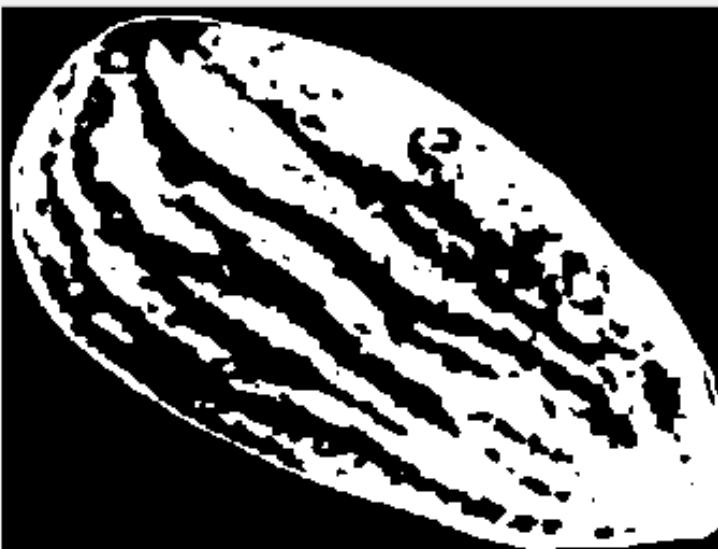






# Aprendizaje supervisado: entrenamiento

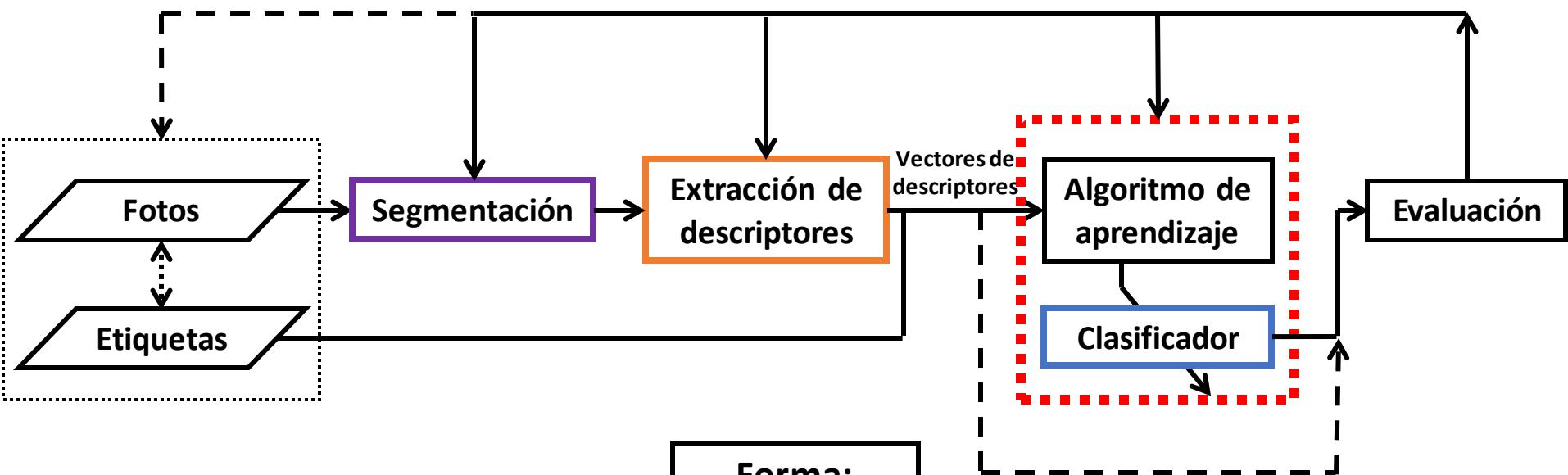




$V = ( medida1 ; medida2; medida3; \dots ; medidaN )$

$V = ( RAellipse ; altura\_caja ; extensión ; solidez;$   
 $media\_H ; desviación\_H ; media\_a^* ; media\_b^* ;$   
 $área\_de\_raspaduras )$

# Aprendizaje supervisado: entrenamiento



**Prototipo:**  
Espejos  
Fondo blanco  
Retroiluminación

Imagen retroiluminada

Método de Otsu

Fotos

Etiquetado manual

**Forma:**  
RA elipse  
RA Caja  
Altura caja  
Extensión  
Solidez

**Color:**  
Media H  
Desviación H  
Media CIELAB  
Raspaduras

**Textura:**  
Arrugas

Entrenamiento y Evaluación

Etapas independientes

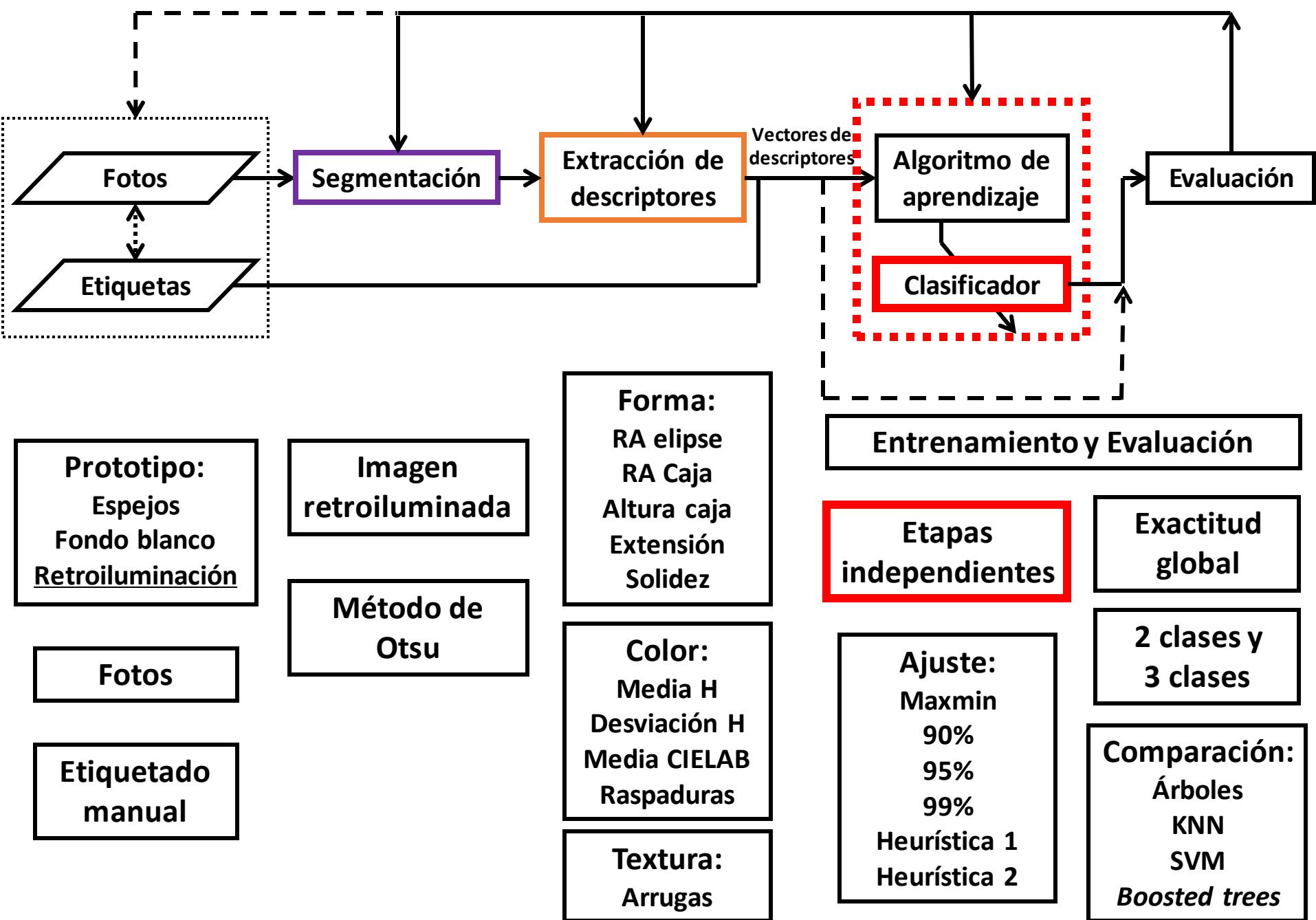
Exactitud global

2 clases y 3 clases

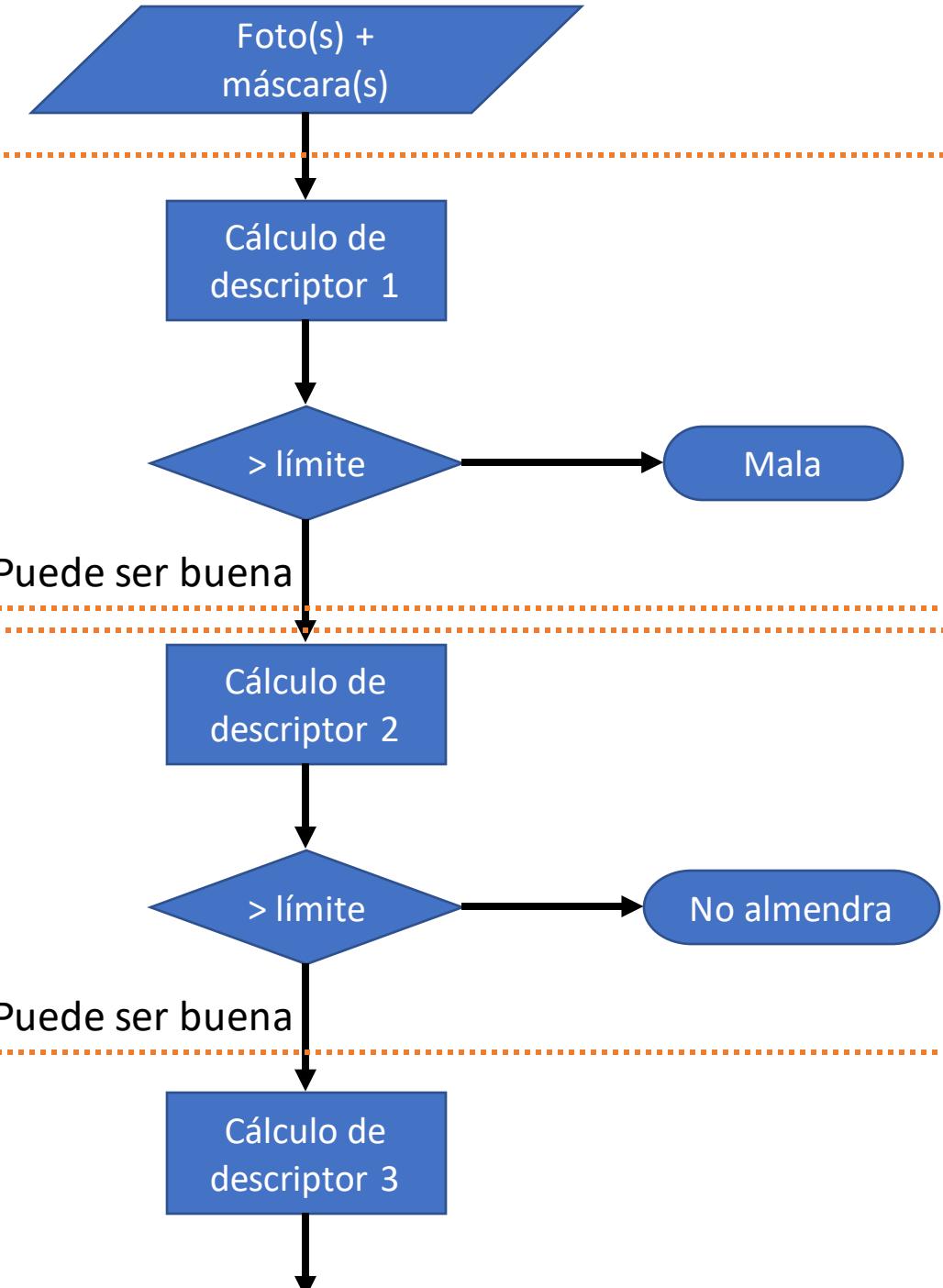
**Ajuste:**  
Maxmin  
90%  
95%  
99%  
Heurística 1  
Heurística 2

**Comparación:**  
Árboles  
KNN  
SVM  
*Boosted trees*

# Aprendizaje supervisado: entrenamiento

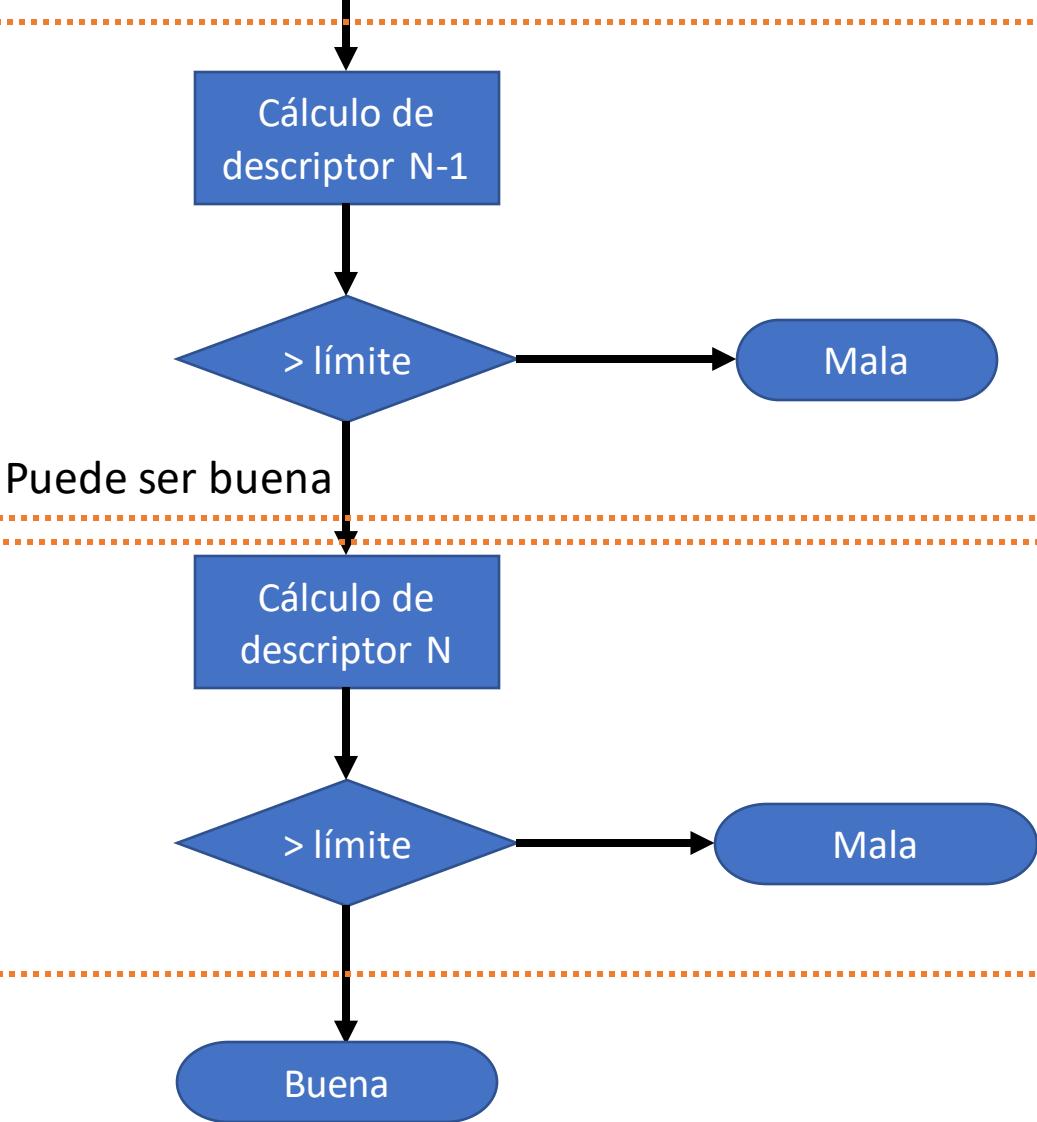


## Etapa clasificadora 1



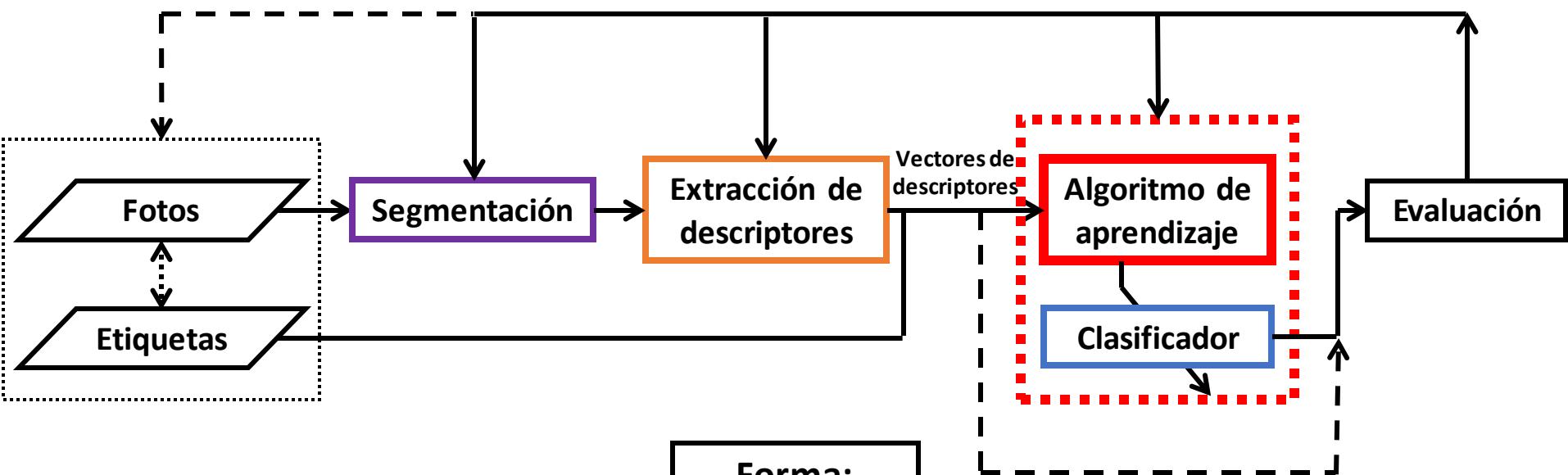
## Etapa clasificadora 2

## Etapa clasificadora N-1



## Etapa clasificadora N

# Aprendizaje supervisado: entrenamiento



**Prototipo:**  
Espejos  
Fondo blanco  
Retroiluminación

Imagen retroiluminada

Método de Otsu

Fotos

Etiquetado manual

**Forma:**  
RA elipse  
RA Caja  
Altura caja  
Extensión  
Solidez

**Color:**  
Media H  
Desviación H  
Media CIELAB  
Raspaduras

**Textura:**  
Arrugas

Entrenamiento y Evaluación

Etapas independientes

Exactitud global

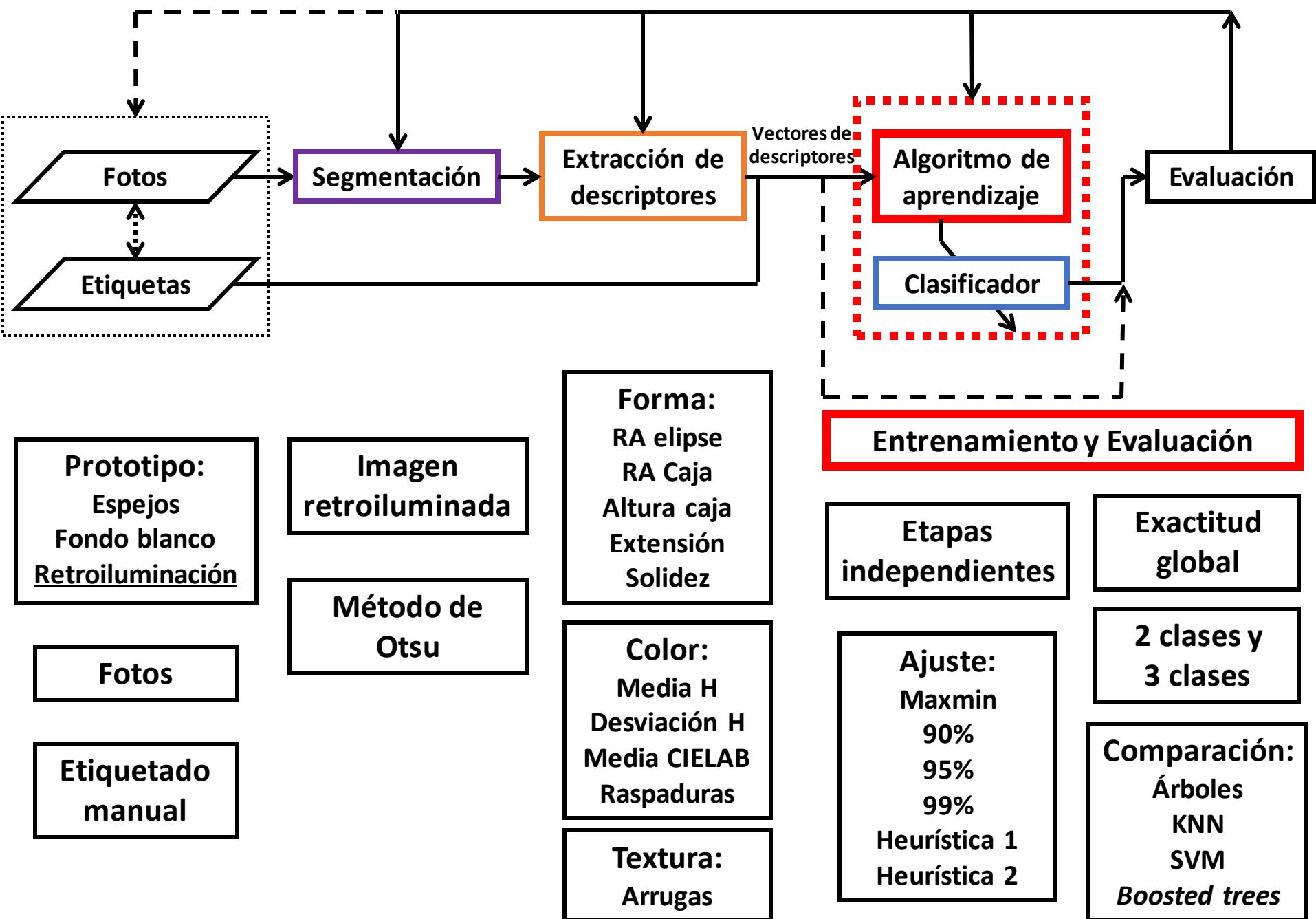
2 clases y 3 clases

**Ajuste:**  
Maxmin  
90%  
95%  
99%

Heurística 1  
Heurística 2

**Comparación:**  
Árboles  
KNN  
SVM  
*Boosted trees*

# Aprendizaje supervisado: entrenamiento

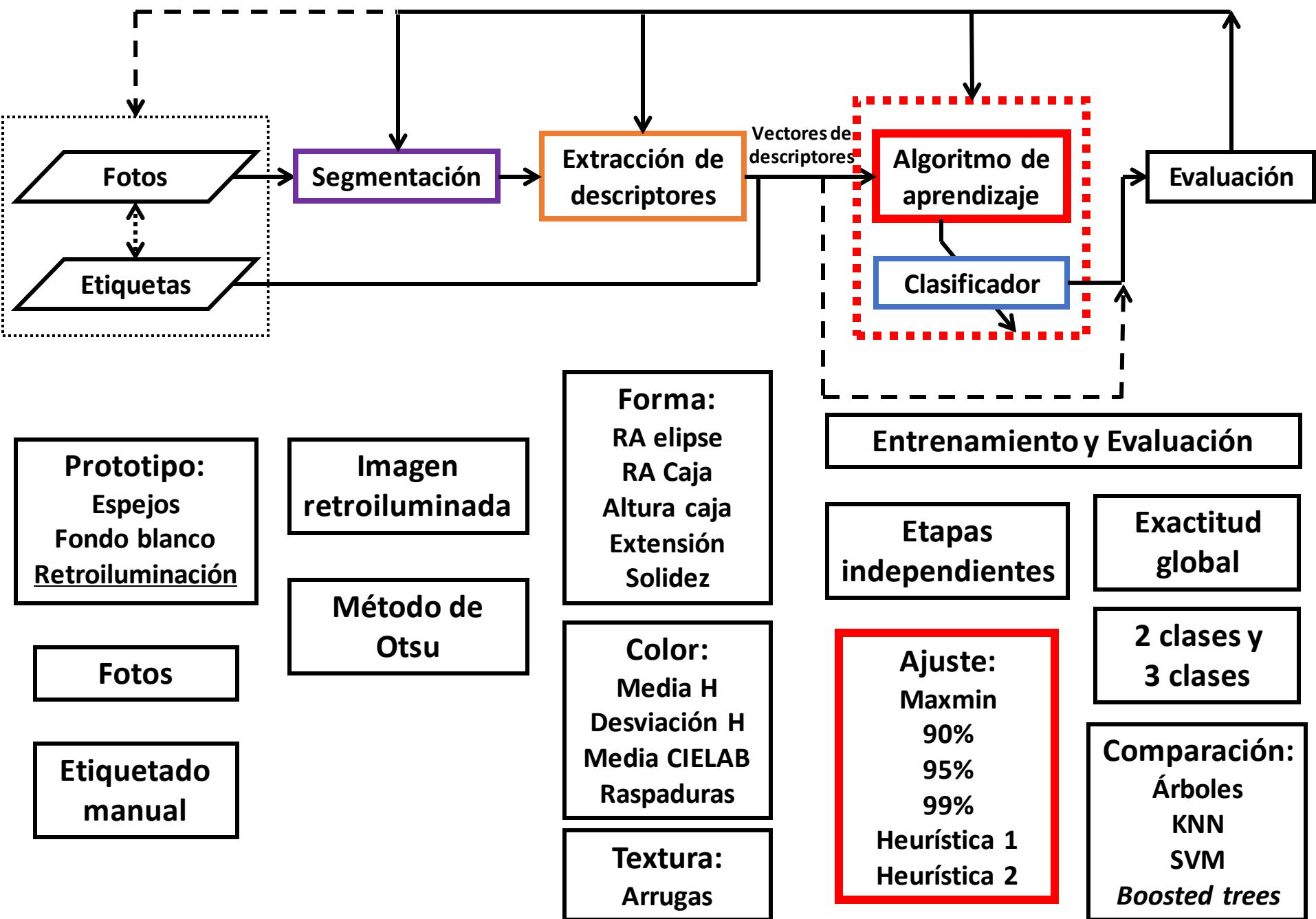




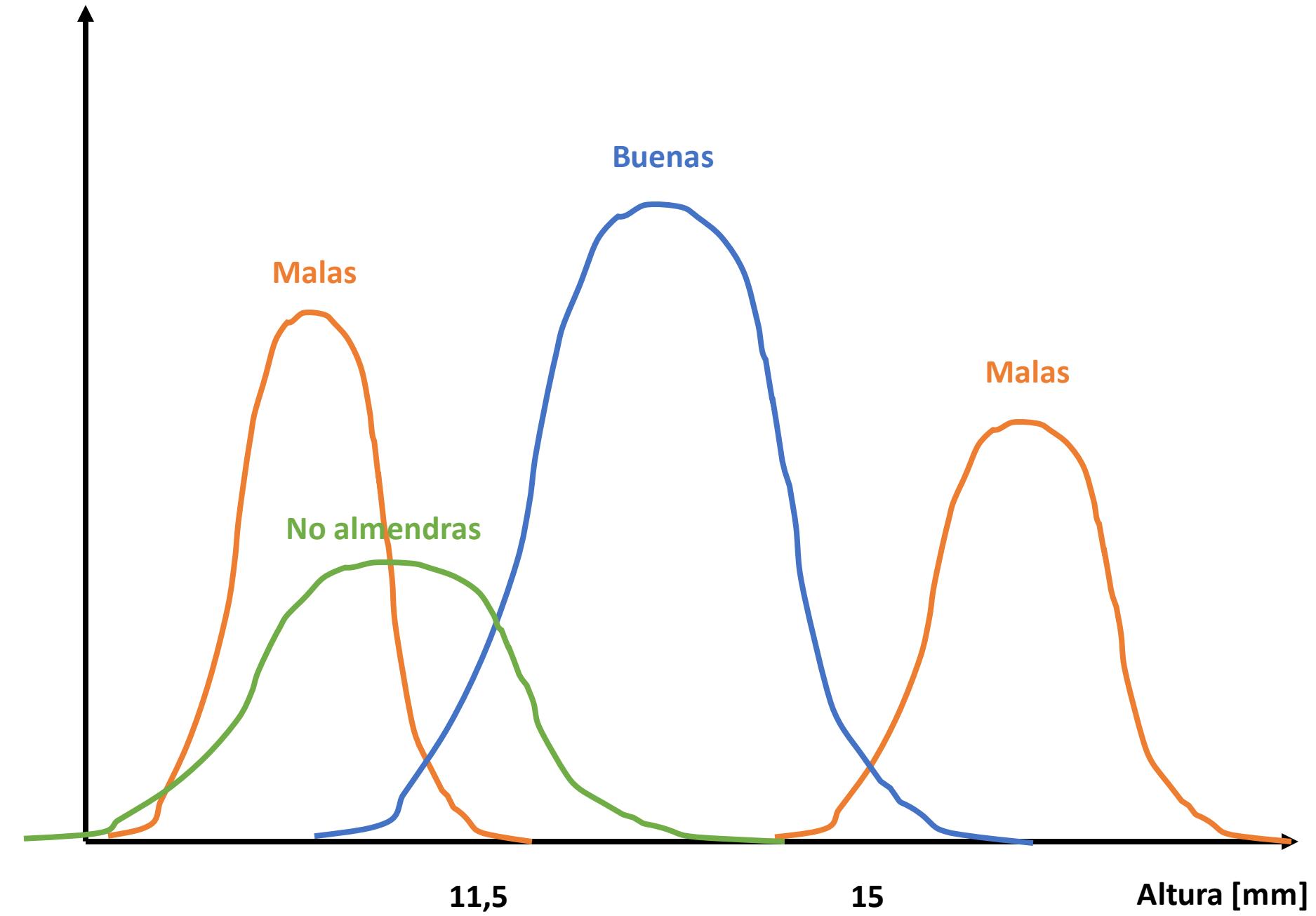
**Entrenamiento /  
Ajuste**

**Evaluación**

# Aprendizaje supervisado: entrenamiento

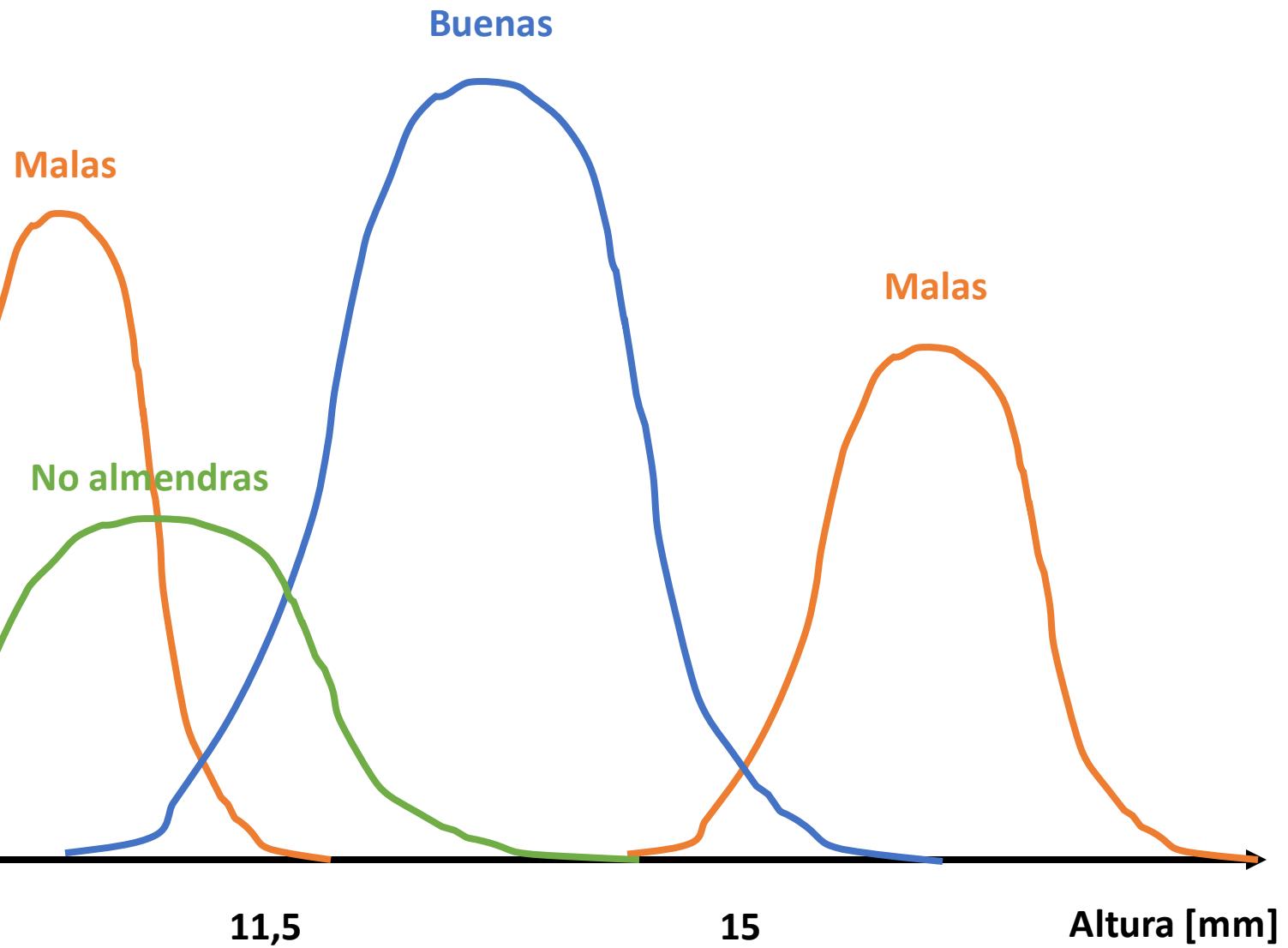


Probabilidad

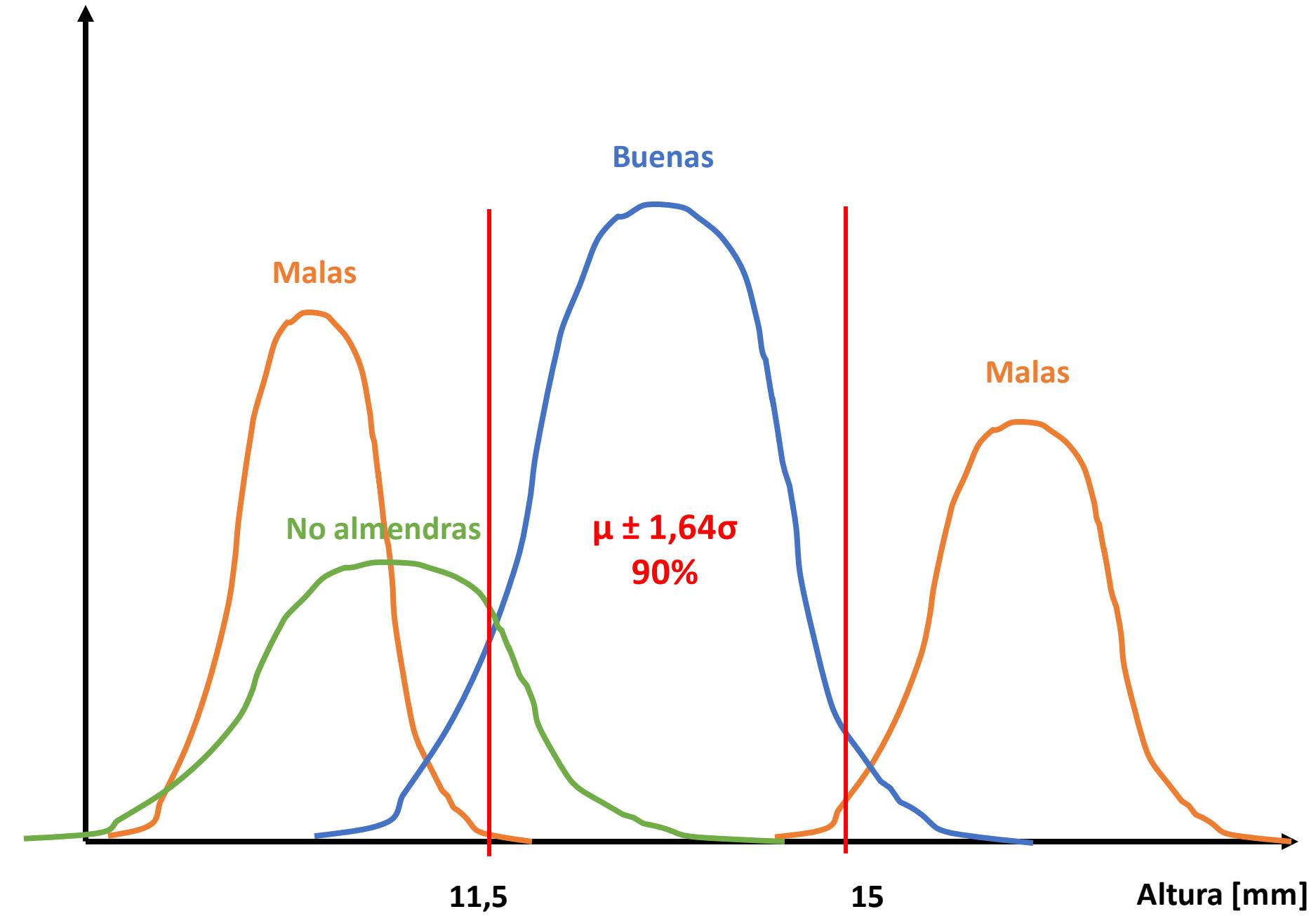


Probabilidad

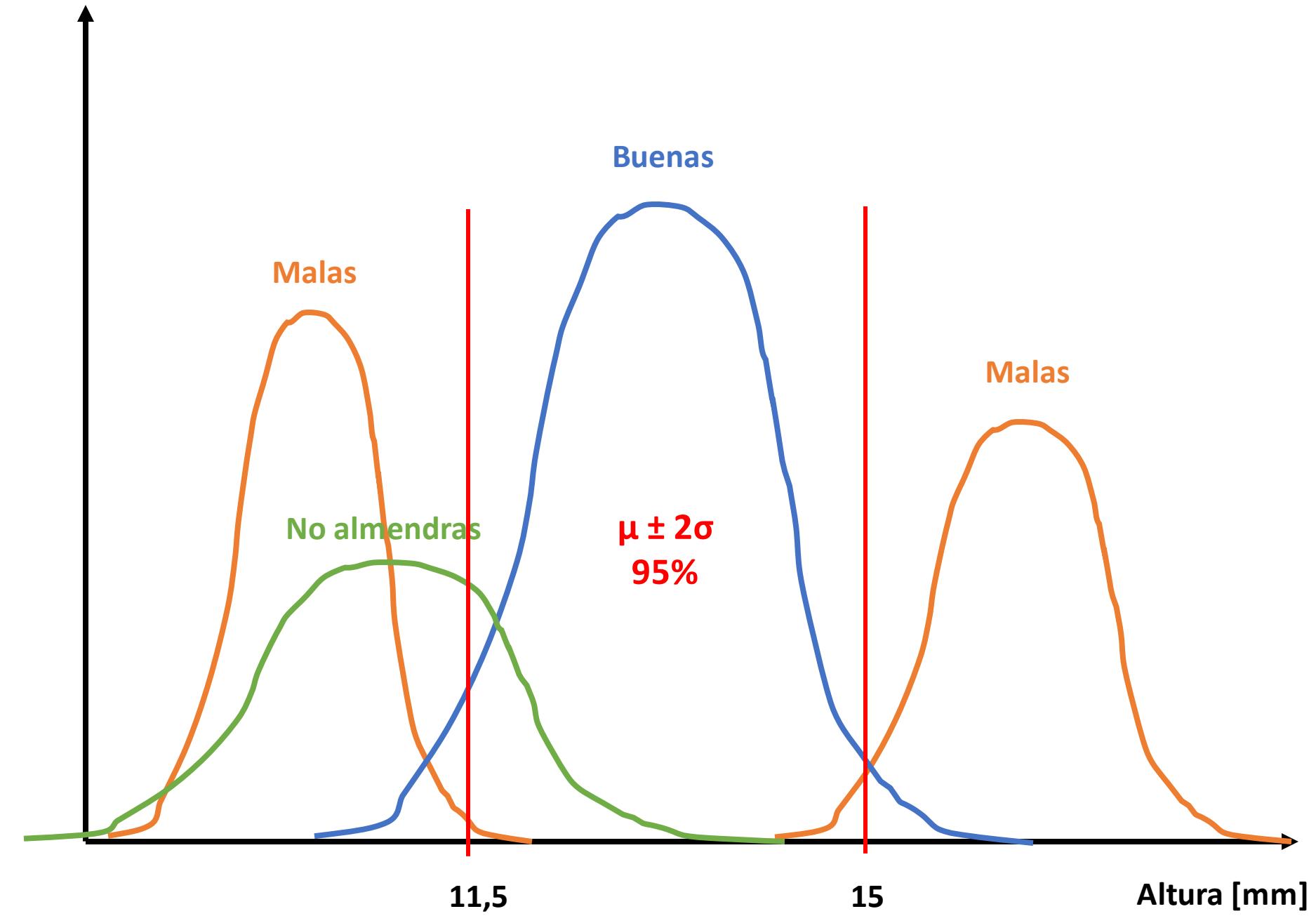
Media  $\mu$   
Desviación estándar  $\sigma$



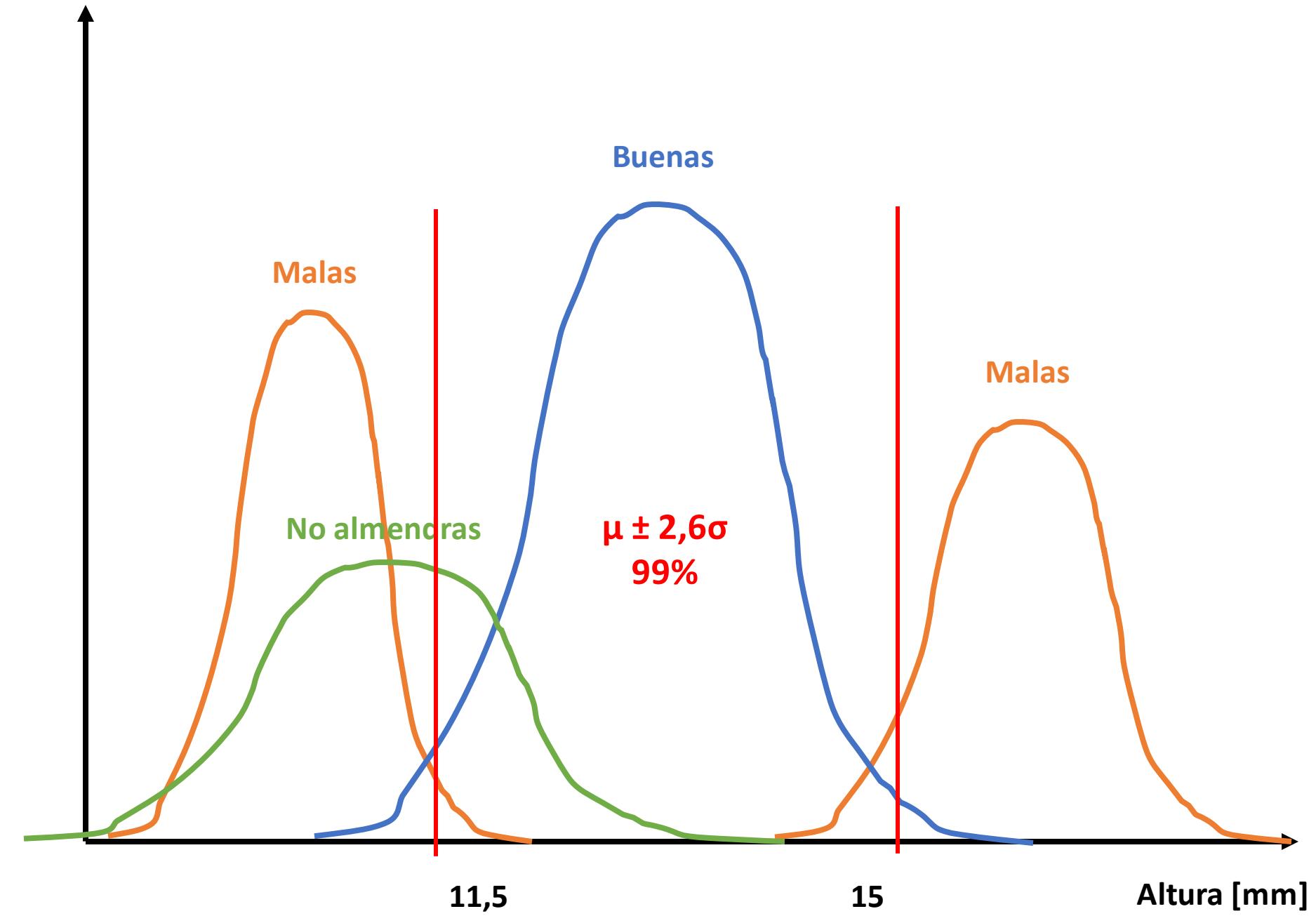
Probabilidad



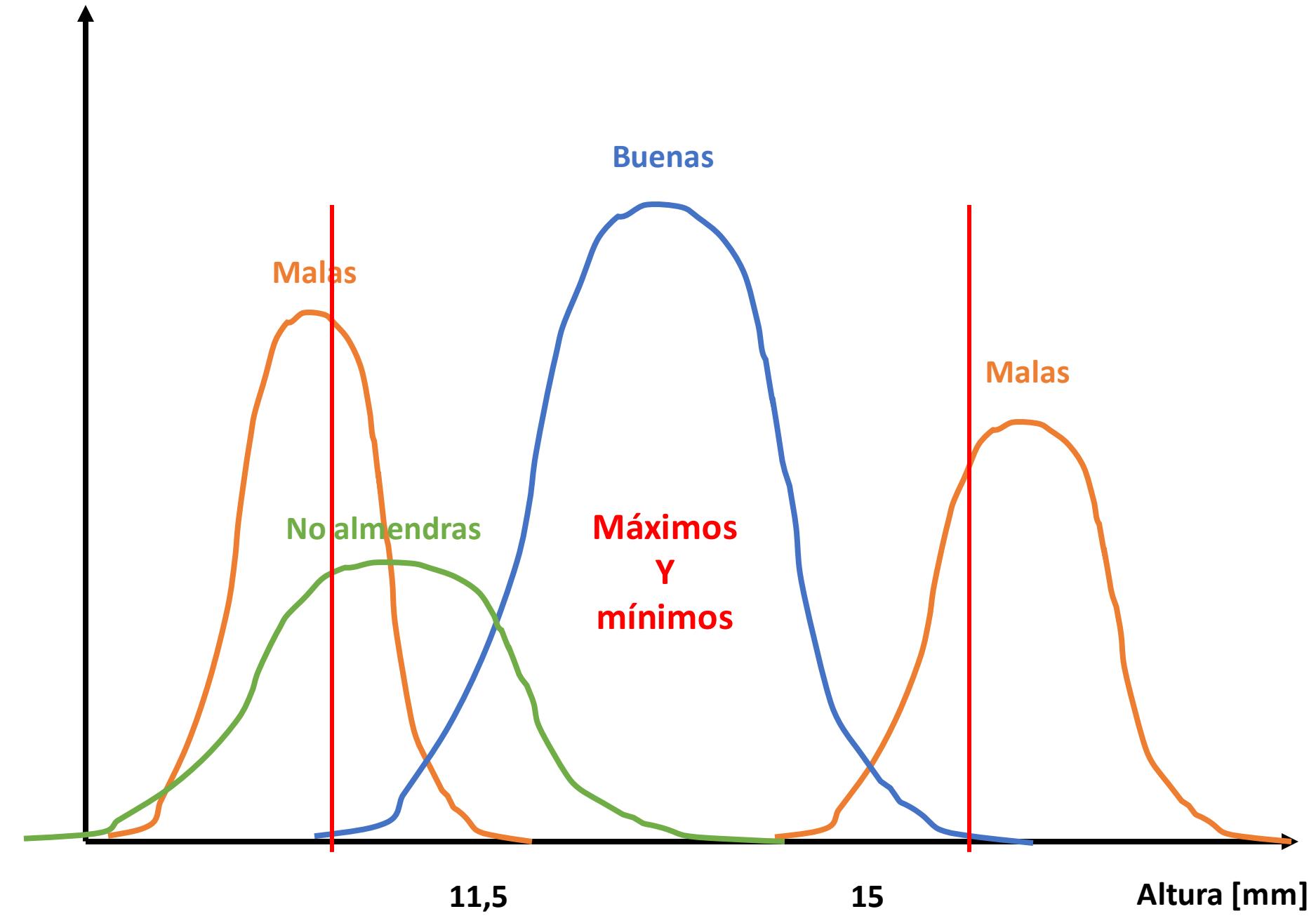
Probabilidad



Probabilidad



Probabilidad



*Heurística*

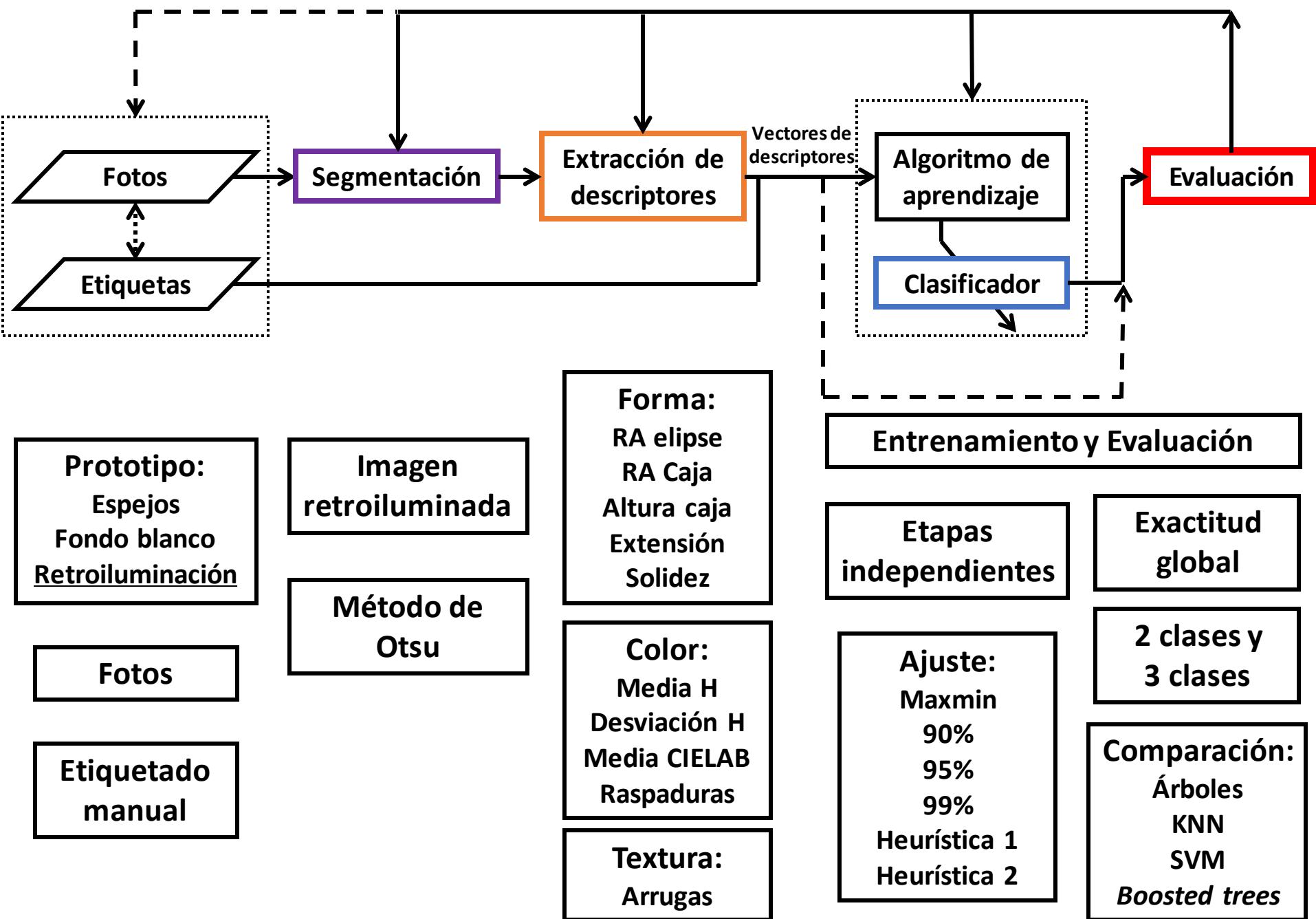
Heurística 1:

95% + Raspaduras<sub>UNECE</sub>

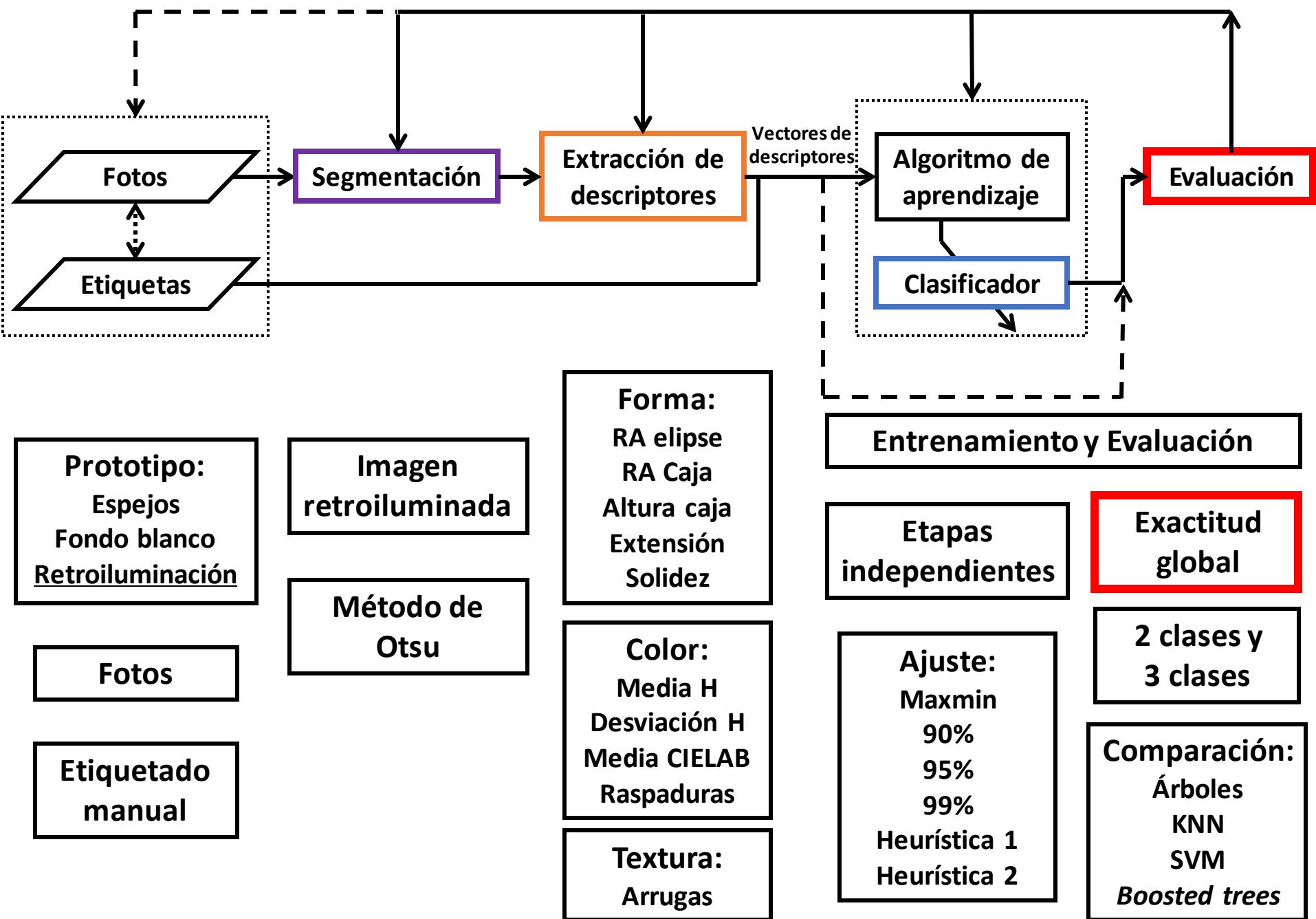
Heurística 2:

99% + Raspaduras<sub>UNECE</sub>

# Aprendizaje supervisado: entrenamiento



# Aprendizaje supervisado: entrenamiento

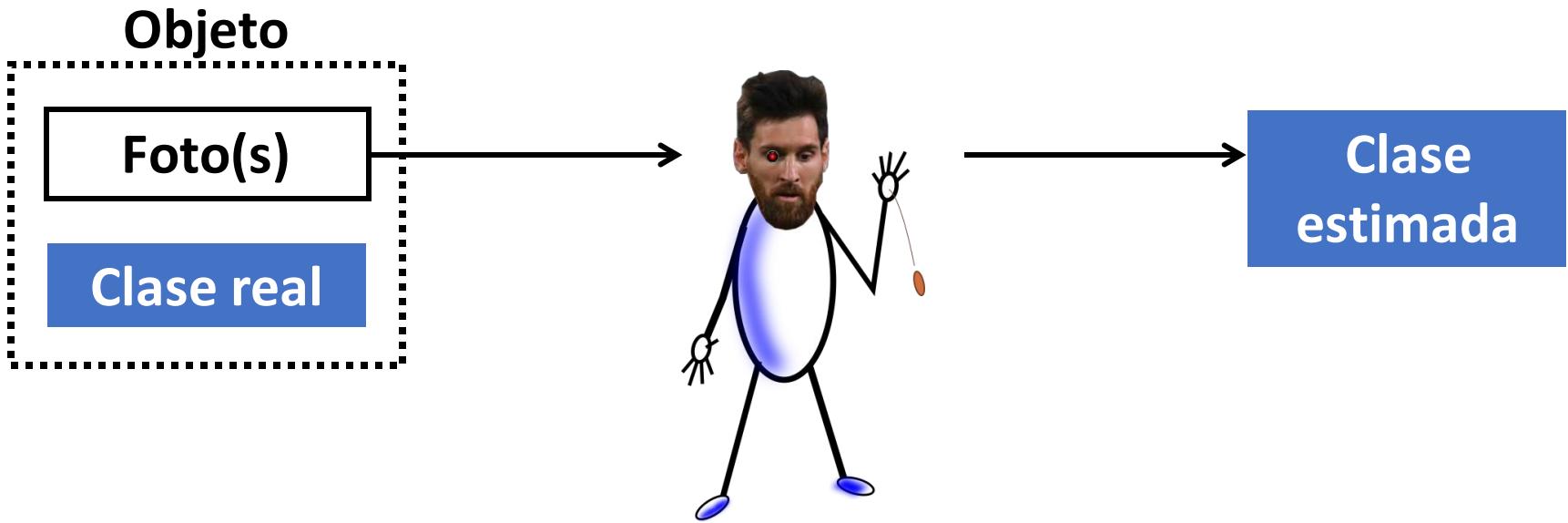




**Entrenamiento /  
Ajuste**

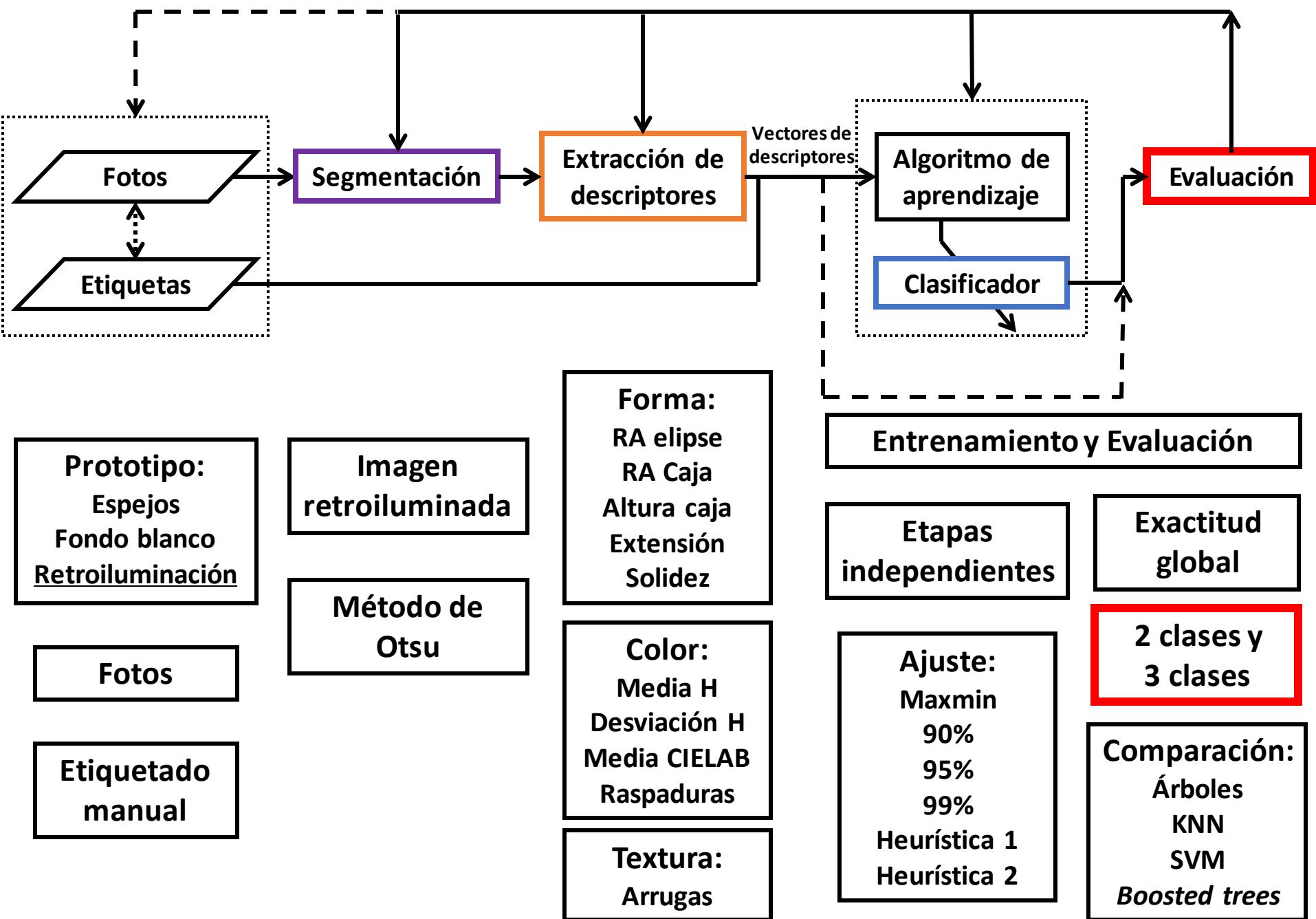


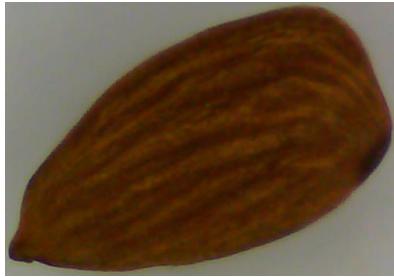
**Evaluación**



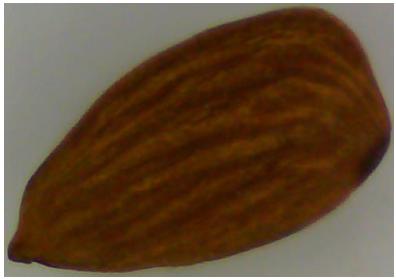
Exactitud global = objetos clasificados correctamente  
total de objetos

# Aprendizaje supervisado: entrenamiento





**VS**



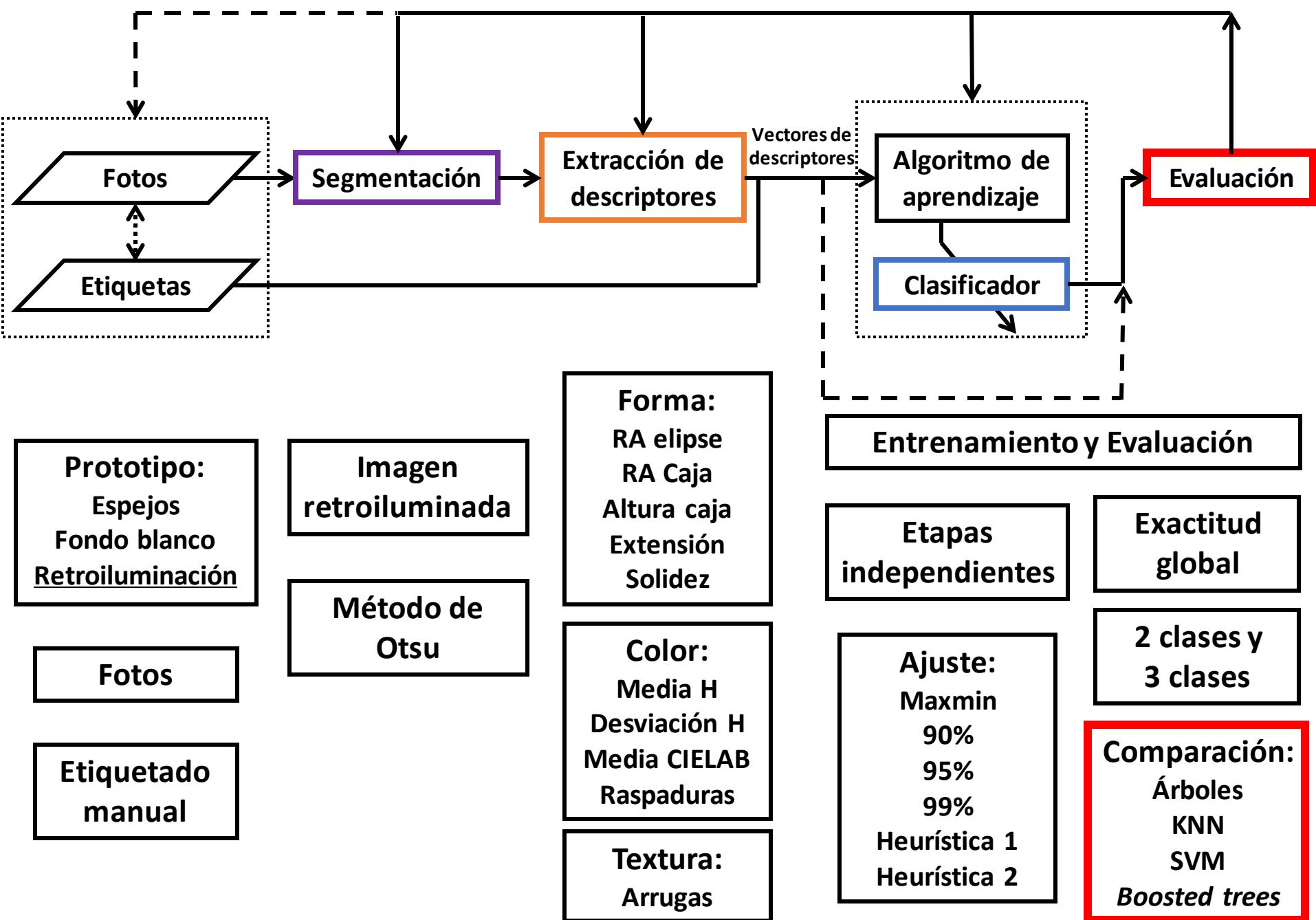
**VS**



**VS**

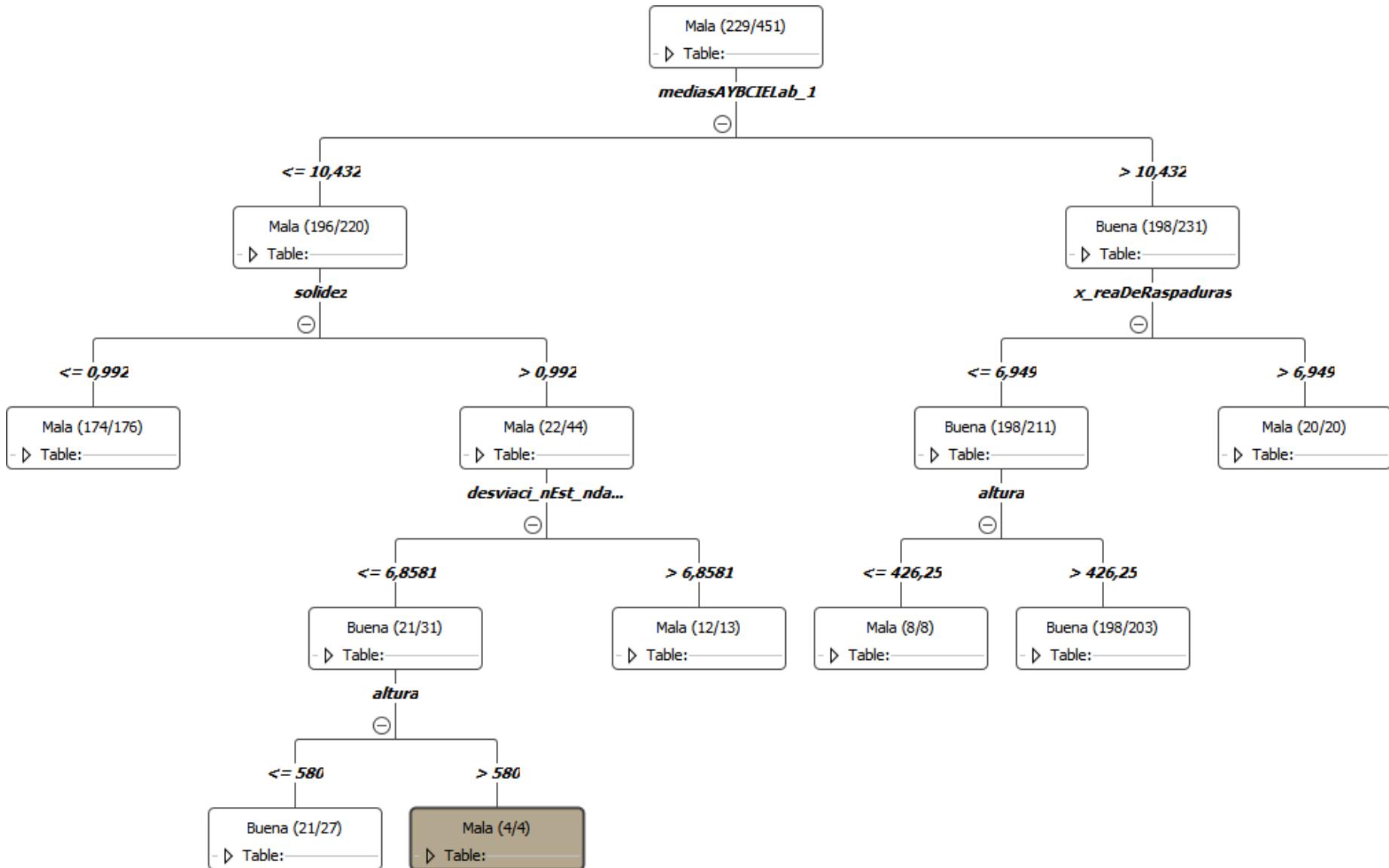


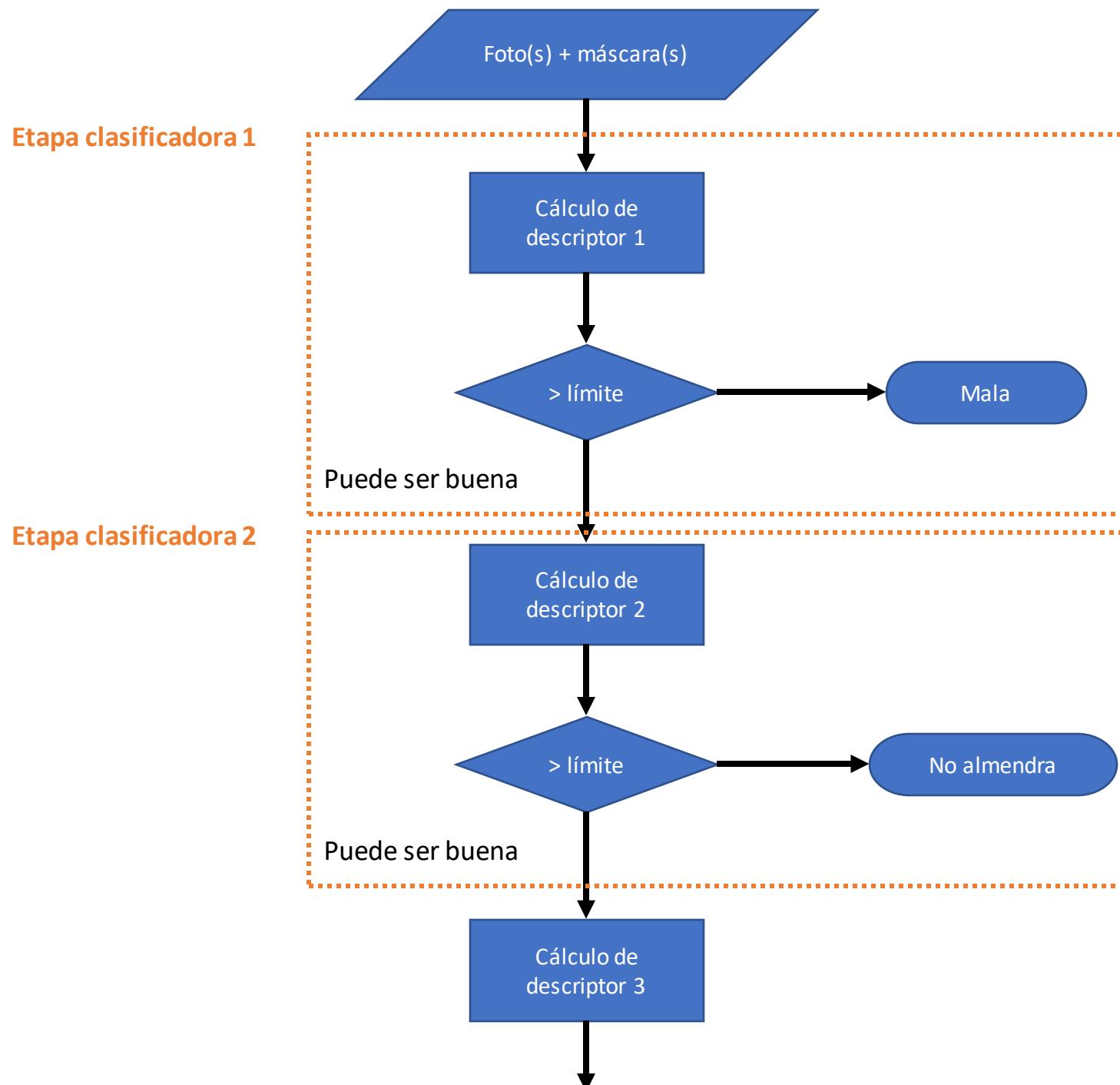
# Aprendizaje supervisado: entrenamiento



*Decision trees*

Árboles de decisión

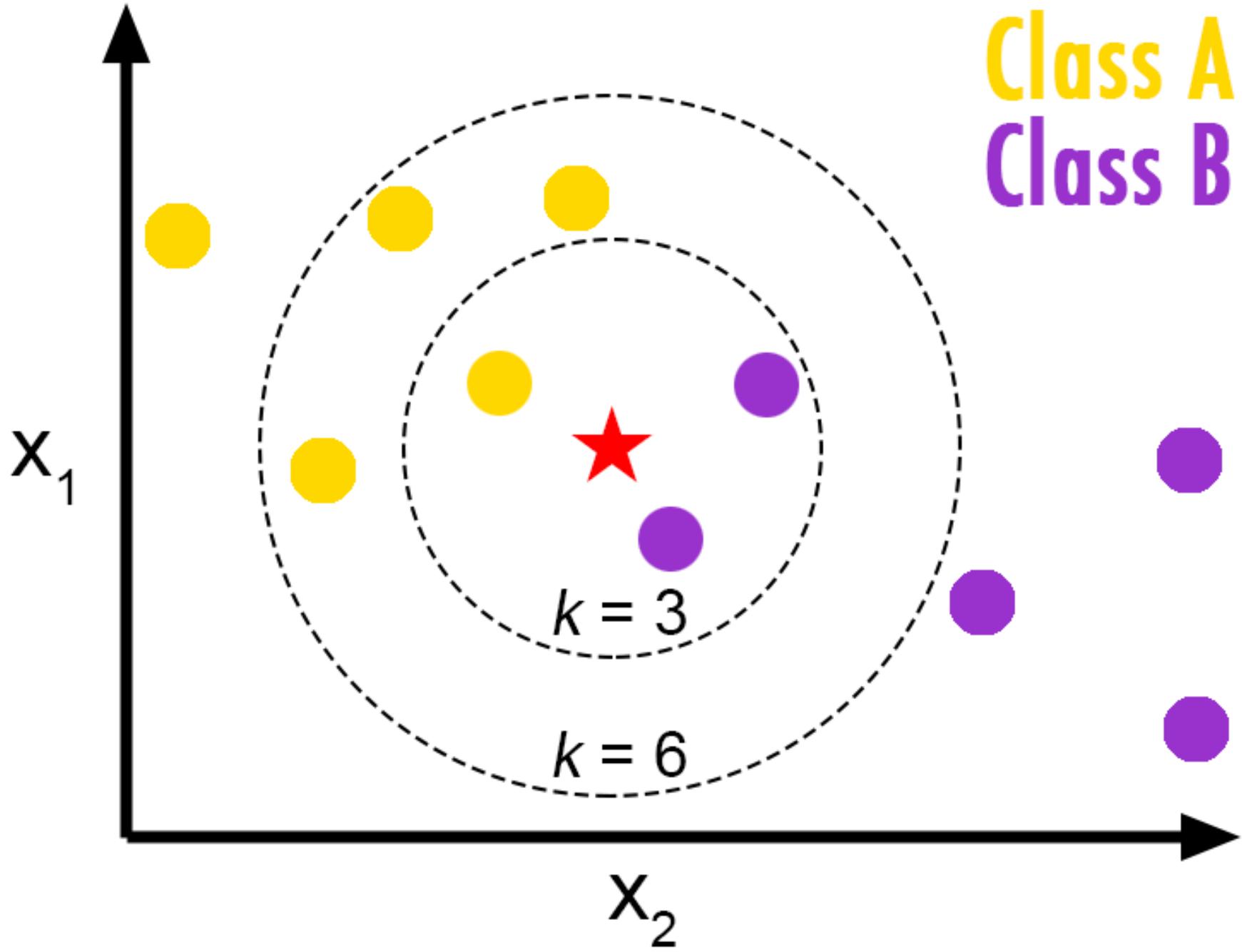




KNN

*K-nearest neighbours*

K vecinos más próximos



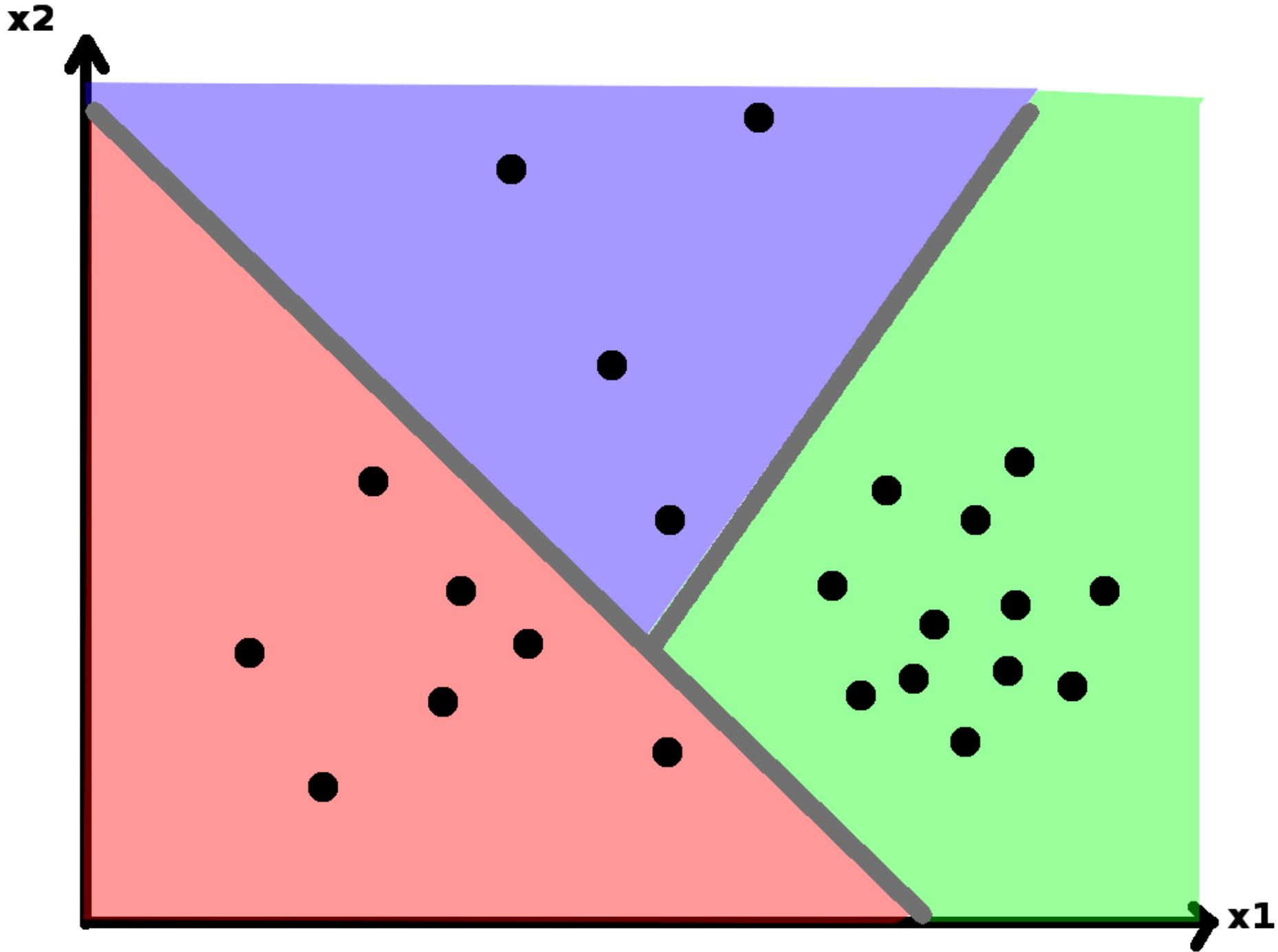
Class A  
Class B

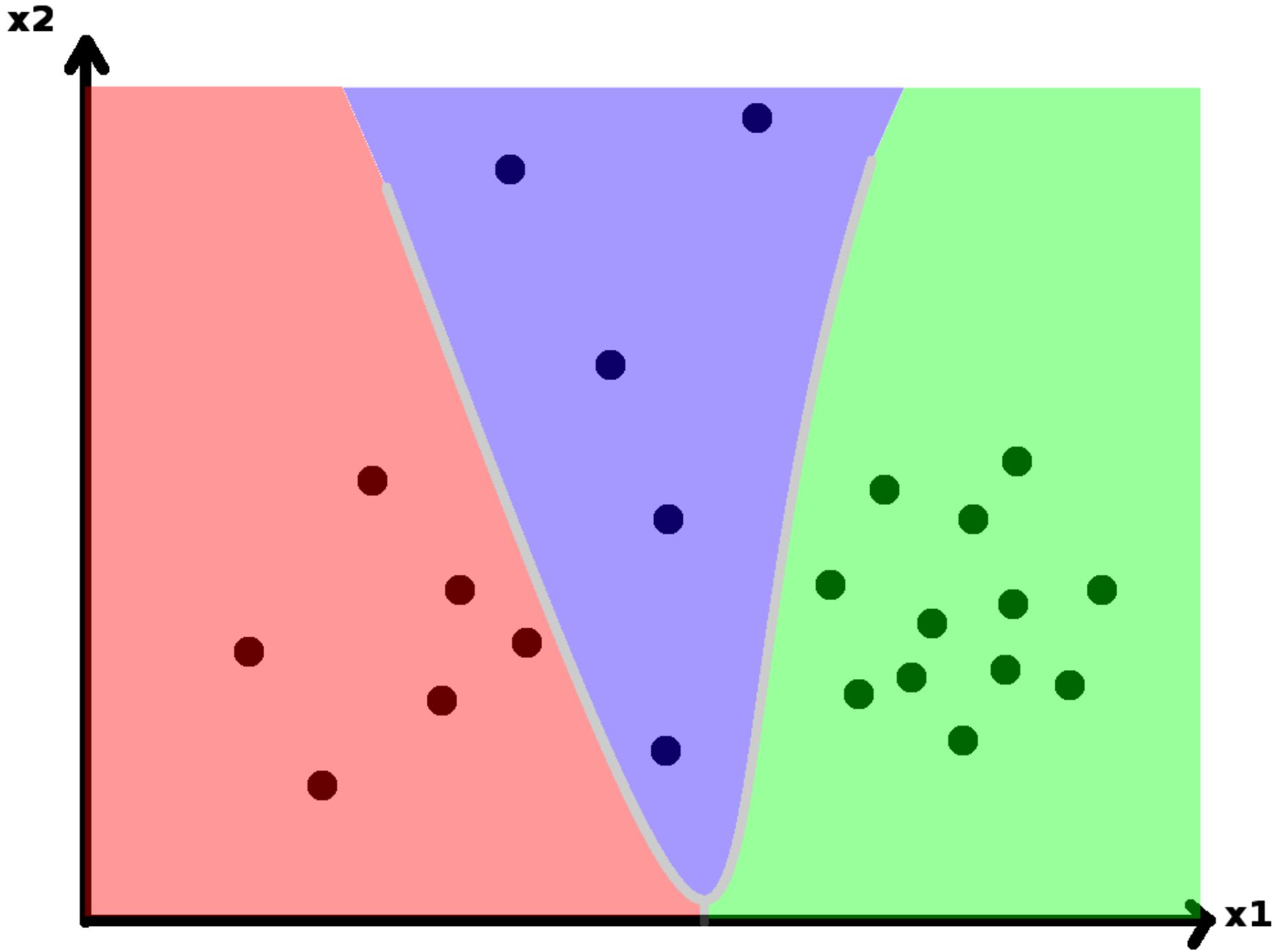
# SVM

# *Support Vector Machines*

Máquinas de vector soporte

Máquinas de soporte vectorial





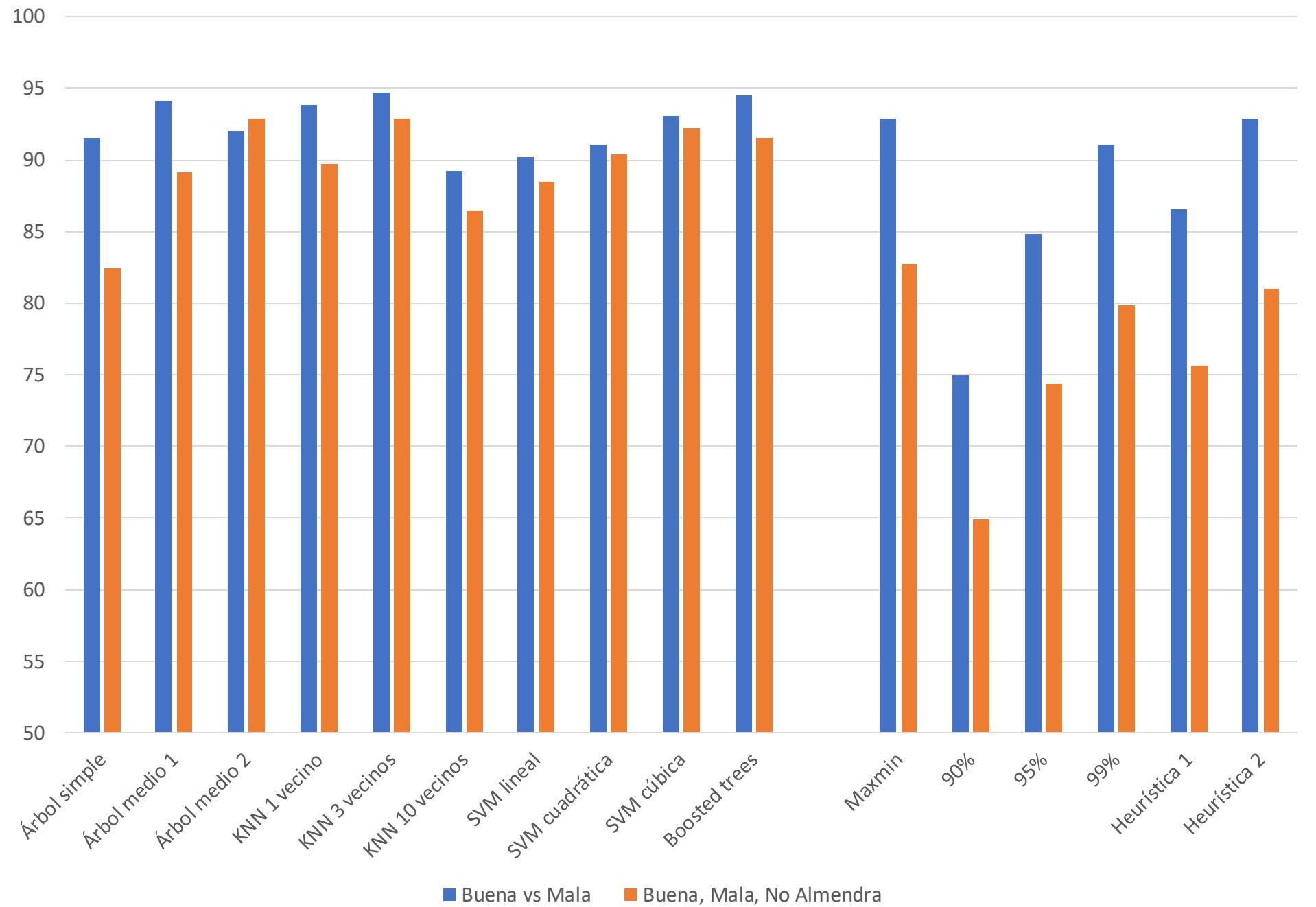
# *Boosted trees*

¿Árboles reforzados?

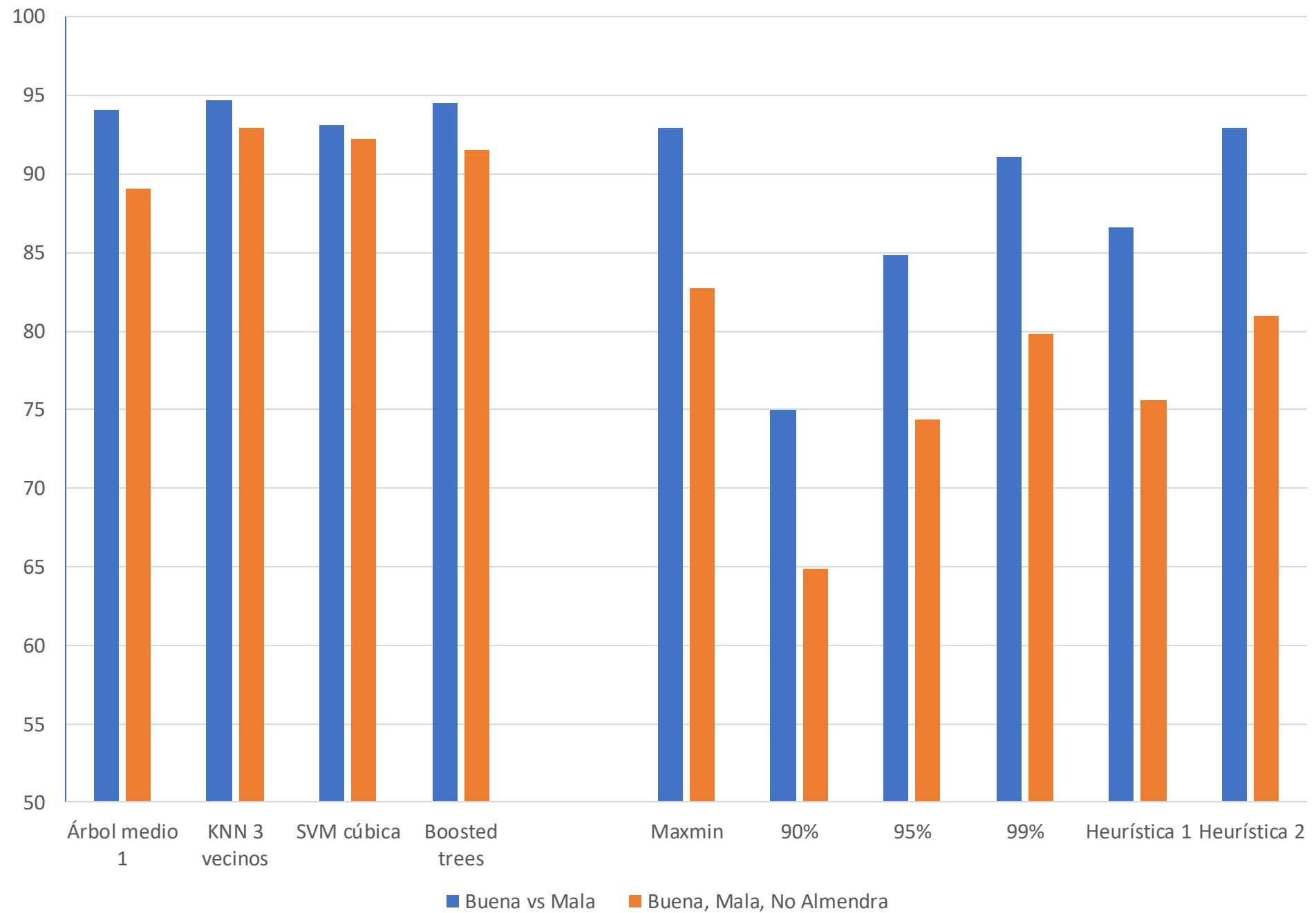
¿Árboles aumentados?

# Resultados

# Exactitud global para distintos clasificadores

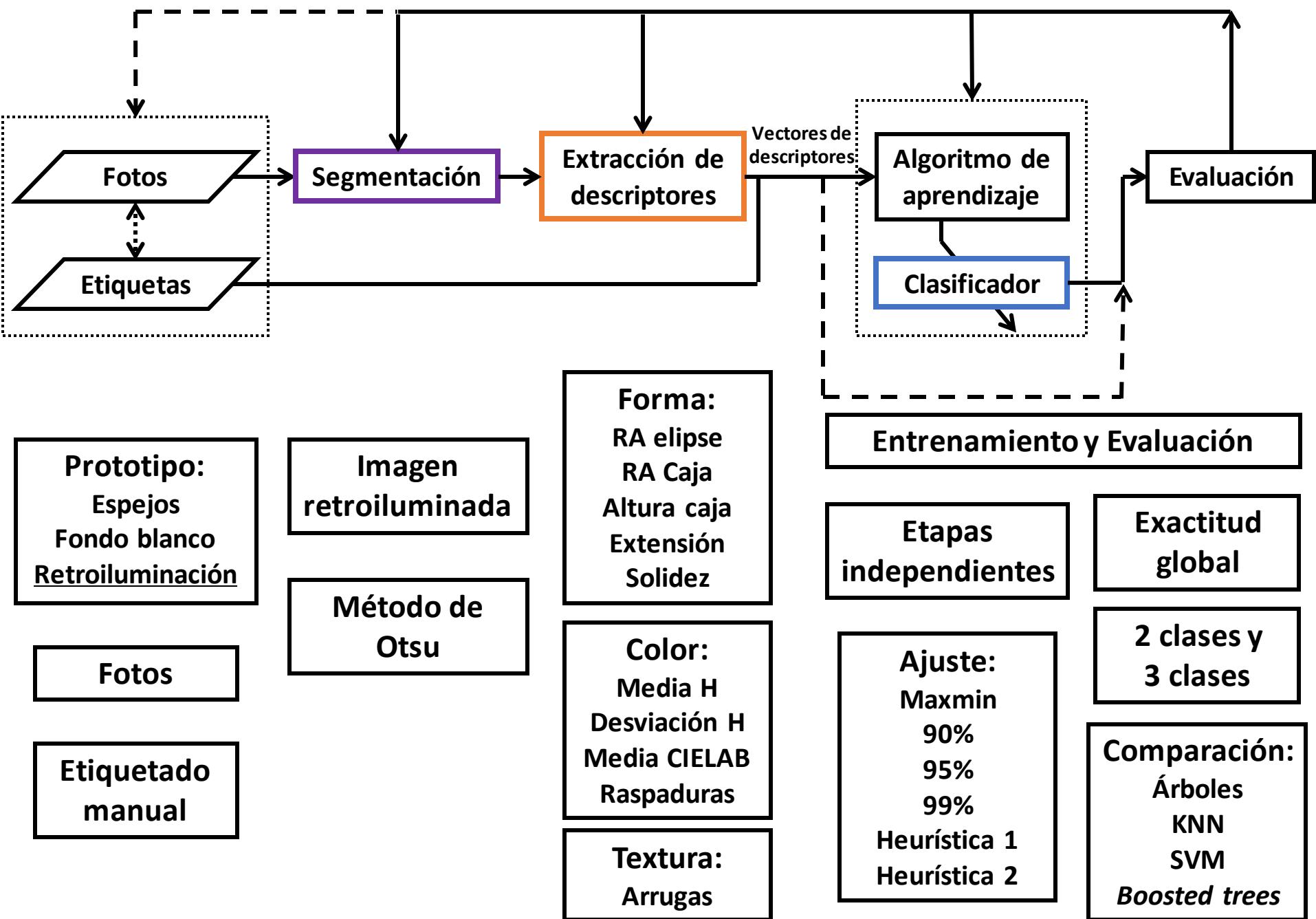


## Exactitud global para distintos clasificadores



# Conclusiones

# Aprendizaje supervisado: entrenamiento



# Problema

- Hablar más con productores

# Sistema de visión

- Cámara web NO
- Determinar sistemas de transporte y rechazo

# Conjuntos de imágenes

- Muchos más objetos
- Criterios más claros para etiquetar

# Evaluación

- Exactitud global no es suficiente
- Tiempo

# Descriptores

- Analizar poder discriminador
- Analizar robustez / invarianza
- Textura
- Tamaño de descriptores
- Faltan...

# Clasificador

- Reusar herramientas probadas y más poderosas
- Primero solo 2 clases. Luego multiclase.

# Descargas



Una estrategia para la clasificación  
óptica de almendras

# ¿Preguntas?

