

XAI para la Comprensión de Sesgos:

Metodologías y herramientas

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¿Quiénes somos?



NextGenerationEU Postdoc

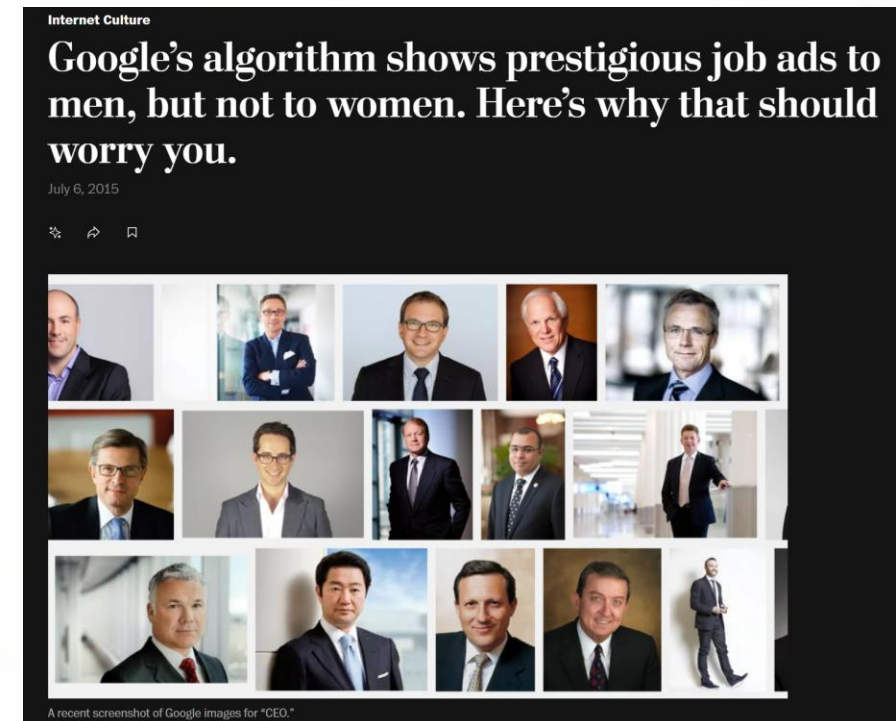
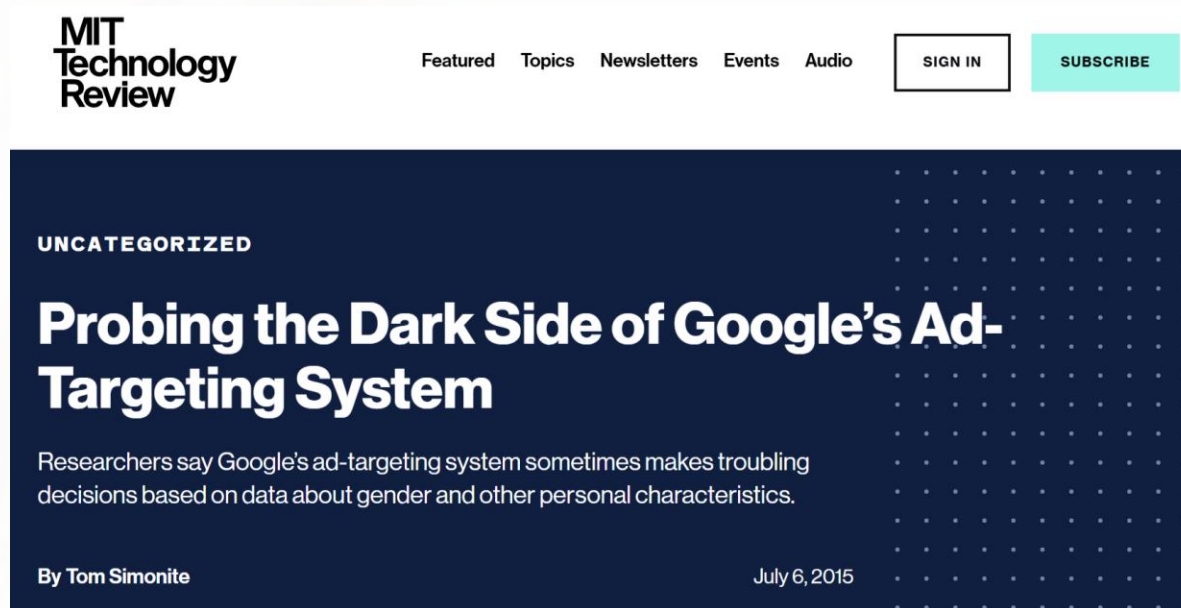


YUFE4Postdoc






Sesgos en AI

Utilizaremos el término “sesgo” para referirnos en sentido amplio al trato desigual, desfavorable e injusto de un grupo respecto de otro.



<https://www.technologyreview.com/2015/07/06/110198/probing-the-dark-side-of-googles-ad-targeting-system/>

Sesgos en AI

Gender Classifier	Darker Male	Darker Female	Lighter Male	Lighter Female	Largest Gap
 Microsoft	94.0% <div><div></div></div>	79.2% <div><div></div></div>	100% <div><div></div></div>	98.3% <div><div></div></div>	20.8% <div><div></div></div>
 FACE++	99.3% <div><div></div></div>	65.5% <div><div></div></div>	99.2% <div><div></div></div>	94.0% <div><div></div></div>	33.8% <div><div></div></div>
 IBM	88.0% <div><div></div></div>	65.3% <div><div></div></div>	99.7% <div><div></div></div>	92.9% <div><div></div></div>	34.4% <div><div></div></div>



<http://gendershades.org/overview.html>

Google's Photo App Still Can't Find Gorillas. And Neither Can Apple's.



Desiree Rios/The New York Times

Eight years after a controversy over Black people being mislabeled as gorillas by image analysis software — and despite big advances in computer vision — tech giants still fear repeating the mistake.

By Nico Grant and Kashmir Hill

May 22, 2023

<https://www.nytimes.com/2023/05/22/technology/ai-photo-labels-google-apple.html>

Sesgos en AI

REVIEW ARTICLE | Originally Published 19 February 2007 | 

 Check for updates

Evidence-Based Guidelines for Cardiovascular Disease Prevention in Women: 2007 Update

Lori Mosca, MD, MPH, PhD, Chair, Carole L. Banka, PhD, Emelia J. Benjamin, MD, Kathy Berra, MSN, NP, Cheryl Bushnell, MD, Rowena J. Dolor, MD, MHS, Theodore G. Ganiats, MD, ... [SHOW ALL ...](#), and for the Expert Panel/Writing Group | [AUTHOR INFO & AFFILIATIONS](#)

Circulation • Volume 115, Number 11 • <https://doi.org/10.1161/CIRCULATIONAHA.107.181546>

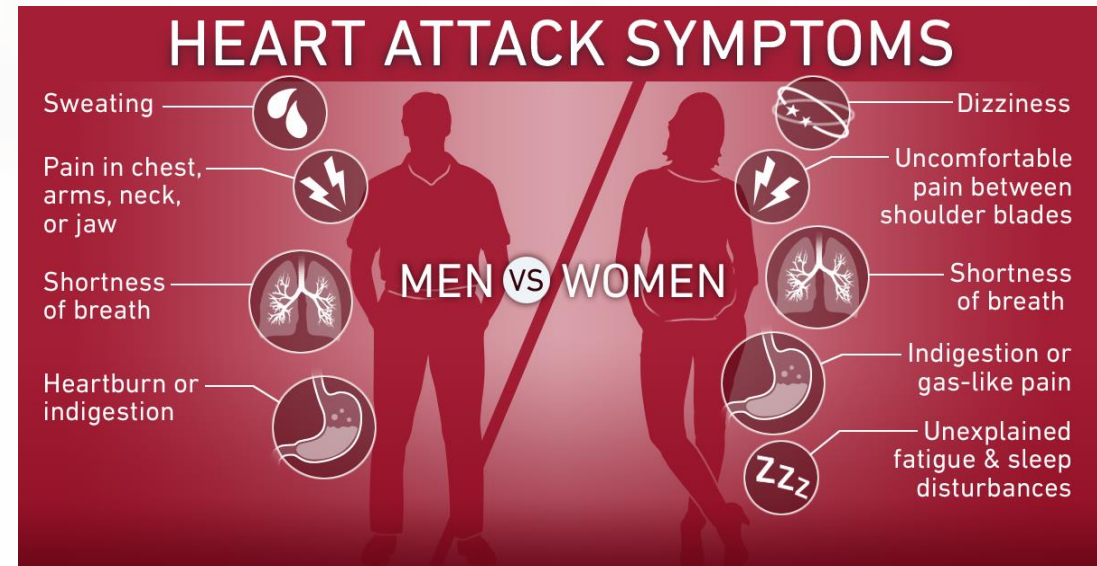
Perspective | [Open access](#) | Published: 21 November 2024

Artificial intelligence bias in the prediction and detection of cardiovascular disease

[Ariana Mihan](#), [Ambarish Pandey](#) & [Harriette G. C. Van Spall](#) 

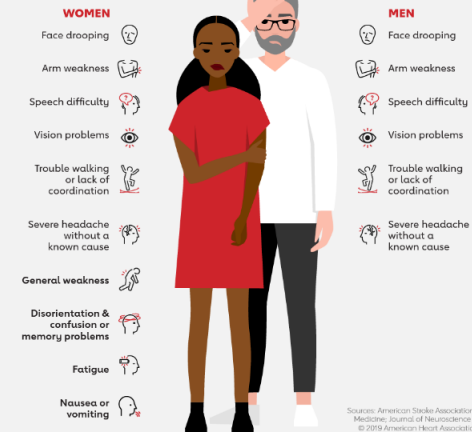
[npj Cardiovascular Health](#) **1**, Article number: 31 (2024) | [Cite this article](#)

3494 Accesses | 8 Altmetric | [Metrics](#)



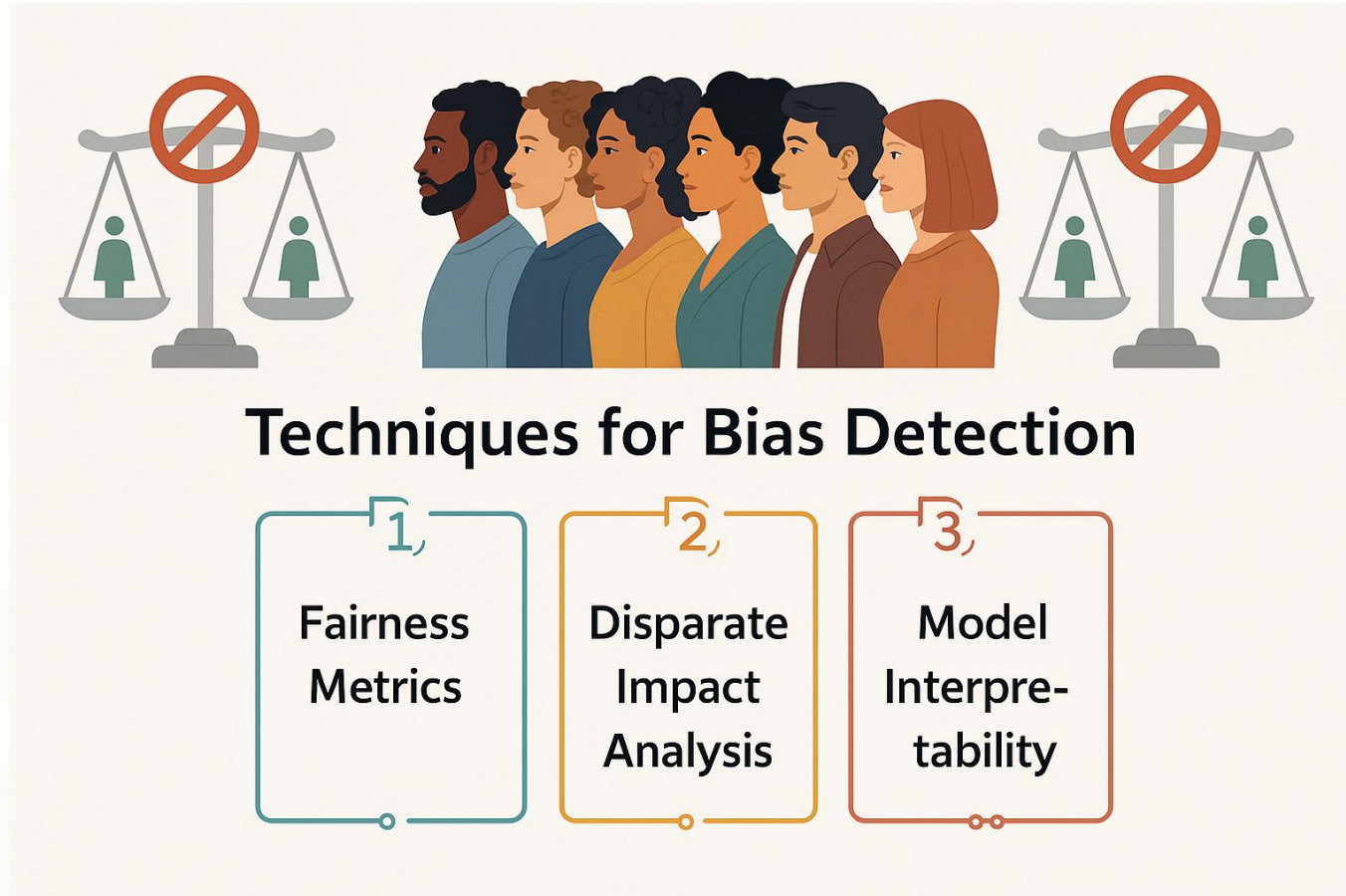
STROKE SYMPTOMS: WOMEN VS. MEN

Men and women share a common set of stroke symptoms. But women also can experience more subtle warning signs.



Source: American Stroke Association. Gender Medicine: Journal of Neuroscience Nursing. © 2019 American Heart Association, Inc.

Sesgos en AI



Toolkits mitigación y detección de sesgos

Fairlearn



<https://github.com/fairlearn/fairlearn>

AIF360



<https://github.com/Trusted-AI/AIF360>

<https://github.com/datamllab/awesome-fairness-in-ai>

El derecho a una explicación

European Union regulations on algorithmic decision-making and a “right to explanation”

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¹Oxford Internet Institute, Oxford

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²Department of Statistics, University of Oxford,
24-29 St Giles', Oxford OX1 3LB, United Kingdom

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Abstract

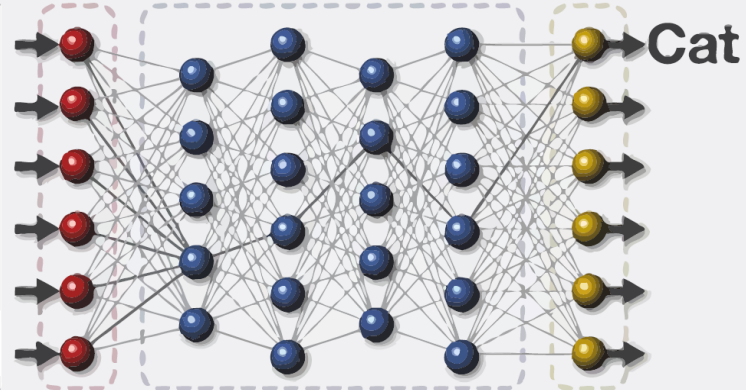
We summarize the potential impact that the European Union's new General Data Protection Regulation will have on the routine use of machine learning algorithms. Slated to take effect as law across the EU in 2018, it will restrict automated individual decision-making (that is, algorithms that make decisions based on user-level predictors) which “significantly affect” users. The law will also effectively create a “right to explanation,” whereby a user can ask for an explanation of an algorithmic decision that was made about them. We argue that while this law will pose large challenges for industry, it highlights opportunities for computer scientists to take the lead in designing algorithms and evaluation frameworks which avoid discrimination and enable explanation.

<https://arxiv.org/abs/1606.08813>



Inteligencia Artificial Explicativa (XAI)

Machine Learning System



This is a cat.

Current Explanation

©DARPA

This is a cat:

- It has fur, whiskers, and claws.
- It has this feature:



XAI Explanation

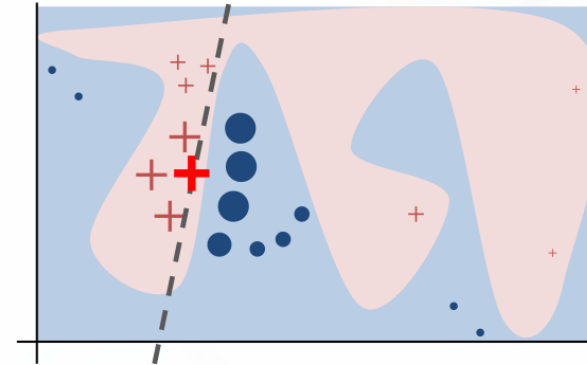
Construyendo explicaciones



SHAP



LIME

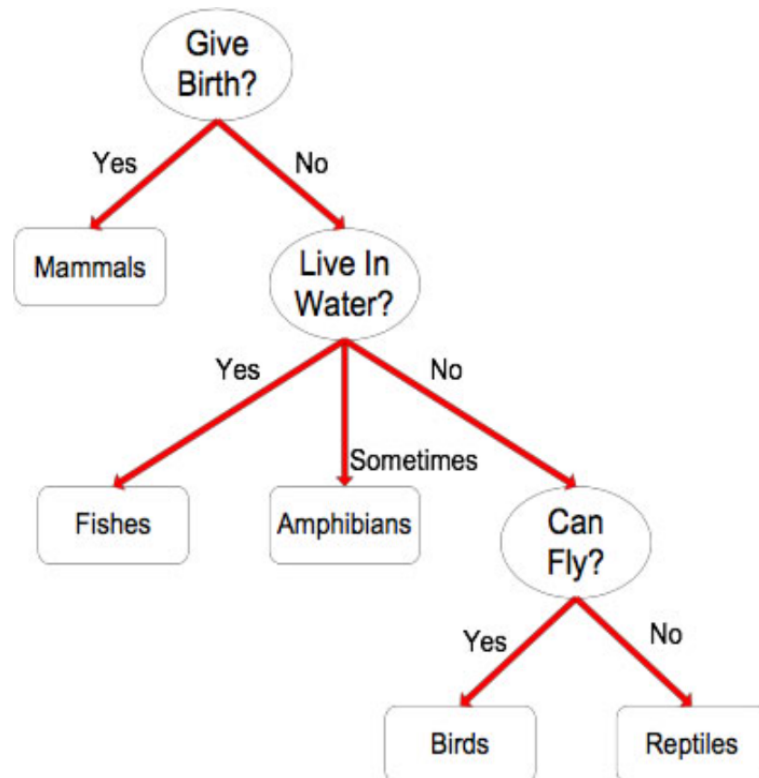


- SHAP: <https://github.com/shap/shap>
- LIME: <https://github.com/marcotcr/lime>
- OmniXAI: <https://github.com/salesforce/omnixai>

Clasificación con reglas

Algunos clasificadores se consideran interpretables, como aquellos que clasifican utilizando un conjunto de reglas 'si...entonces'.

C4.5 Decision Tree versus C4.5rules versus RIPPER



C4.5rules

(Give Birth=No, Can Fly=Yes) → Birds
(Give Birth=No, Live in Water=Yes) → Fishes
(Give Birth=Yes) → Mammals
(Give Birth=No, Can Fly=No, Live in Water=No) → Reptiles
() → Amphibians

RIPPER:

(Live in Water=Yes) → Fishes
(Have Legs=No) → Reptiles
(Give Birth=No, Can Fly=No, Live In Water=No) → Reptiles
(Can Fly=Yes, Give Birth=No) → Birds
() → Mammals

Confusion Matrix for C4.5 versus RIPPER



exFuzzy

¿Qué es exFuzzy?

- Una biblioteca python para realizar XAI utilizando reglas difusas
 - Con especial atención a la explicabilidad y la visualización

	A	B	C	D	E	F	G
1	OrderDa	Region	Rep	Item	Unit	Unit Cos	Total
2	1/6/21	East	Jones	Pencil	95	1.99	189.05
3	1/23/21	Central	Kivell	Binder	50	19.99	999.50
4	2/9/21	Central	Jardine	Pencil	36	4.99	179.64
5	2/26/21	Central	Gill	Pen	27	19.99	539.73
6	3/15/21	West	Sorvino	Pencil	56	2.99	167.44
7	4/1/21	East	Jones	Binder	60	4.99	299.40
8	4/18/21	Central	Andrews	Pencil	75	1.99	149.25
9	5/5/21	Central	Jardine	Pencil	90	4.99	449.10
10	5/22/21	West	Thompso	Pencil	32	1.99	63.68
11	6/8/21	East	Jones	Binder	60	8.99	539.40
12	6/25/21	Central	Morgan	Pencil	90	4.99	449.10
13	7/12/21	East	Howard	Binder	29	1.99	57.71
14	7/29/21	East	Parent	Binder	81	19.99	1,619.19
15	8/15/21	East	Jones	Pencil	35	4.99	174.65
16	9/1/21	Central	Smith	Desk	2	125.00	250.00
17	9/18/21	East	Jones	Desk Set	15	15.00	225.00

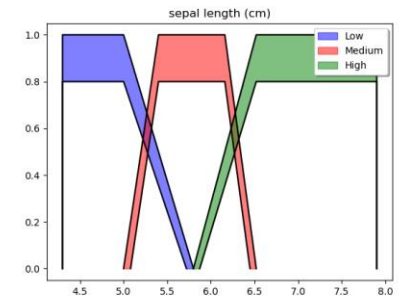
exFuzzy

```
-----
Rules for consequent: setosa
-----
IF petal width (cm) IS Low WITH DS 0.7359951780154956, ACC 0.9444444444444444

Rules for consequent: versicolor
-----
IF petal width (cm) IS Medium WITH DS 0.7630571825431511, ACC 0.90625

Rules for consequent: virginica
-----
IF sepal length (cm) IS High AND petal width (cm) IS High WITH DS 0.5742697564048905, ACC 0.9354838709677419
IF sepal length (cm) IS Low AND petal length (cm) IS High WITH DS 0.005588278153979678, ACC 1.0
```

Cluster	Positivity	Negativity	Subjectivity	Polarity	DS	Acc
1	●	●	●	●	0.07	0.40
	●	●	●	●	0.12	0.66
2	●	●	●	●	0.54	0.89
	●	●	●	●	0.11	0.75
3	●	●	●	●	0.04	0.10
4	-	-	-	-	-	-



¿Porqué exFuzzy?

- Los métodos de clasificación estándar cuentan con numerosos recursos:
 - NN (MLP y DL)
 - SVM
 - Random Forest
- **Scikit Learn** sigue siendo la biblioteca de ciencia de datos más descargada!

¿Porqué exFuzzy?

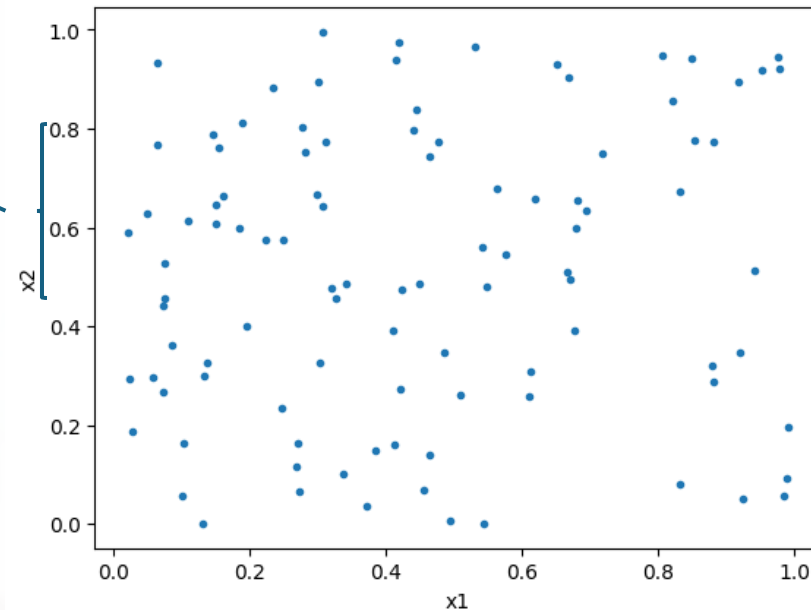
- Los métodos de reglas son técnicas XAI basados en condicionales lógicas:

IF x_1 is A AND x_2 is B THEN do Z/class is Z

¿Porqué exFuzzy?

- Los métodos de reglas son técnicas XAI basados en condicionales lógicas:

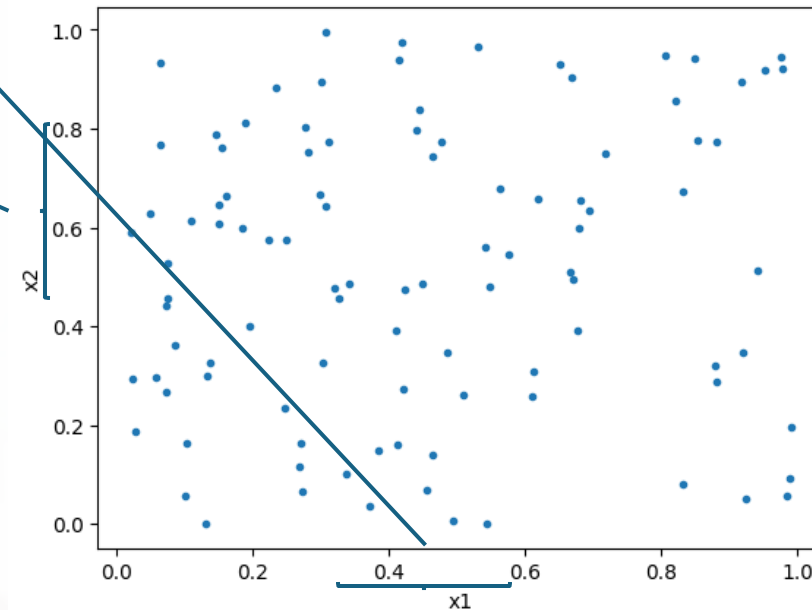
IF x_1 is A AND x_2 is B THEN do Z/ class is Z



¿Porqué exFuzzy?

- Rule-based/logic constrain is another XAI method*:

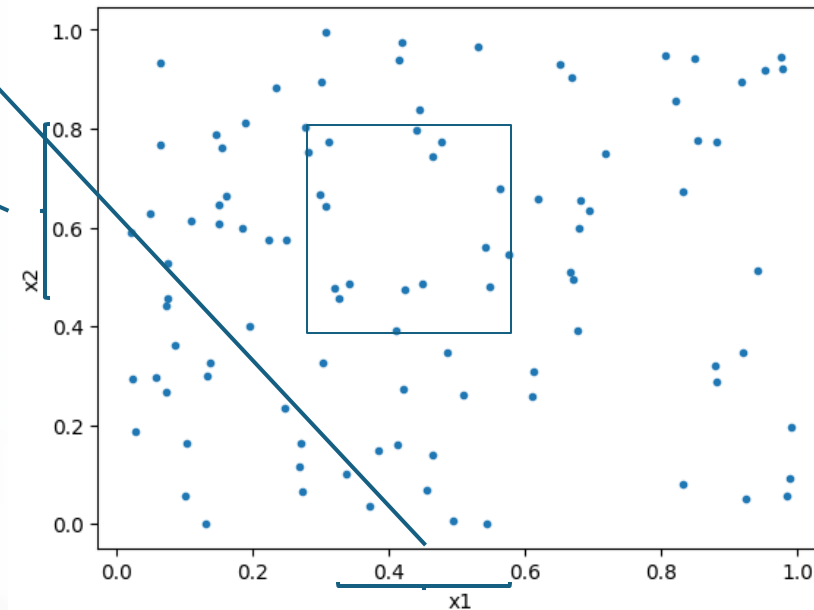
IF x_1 is A AND x_2 is B THEN do Z/ class is Z



Why exFuzzy?

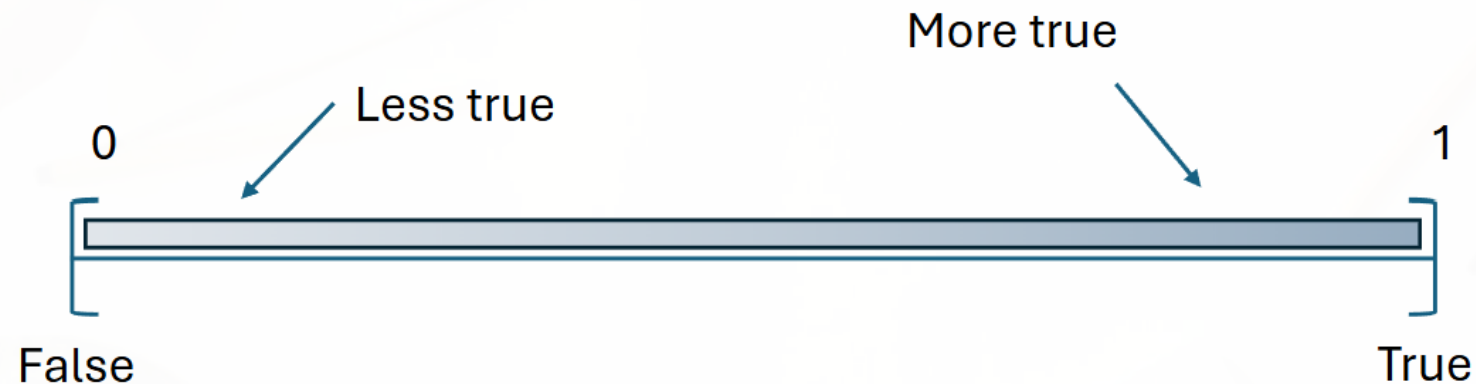
- Los métodos de reglas son técnicas XAI basados en condicionales lógicas:

IF x_1 is A AND x_2 is B THEN do Z/ class is Z



Lógica Difusa

- Nos salimos de la lógica booleana 0/1 blanco/negro.
- Los valores de la lógica difusa son escalas de grises en el intervalo $[0,1]$.



Lógica Difusa



- Temperatura/sensación térmica: **caliente**/frío



- Proximidad: cerca/lejos



- Precios: barato/caro



- Arte: impresionismo/cubismo

Lógica Difusa

- Las reglas difusas son un tipo particular de reglas muy útiles debido a cómo dividen el estado de entrada.

Regla clásica

If blood pressure $< 100\text{mg}$

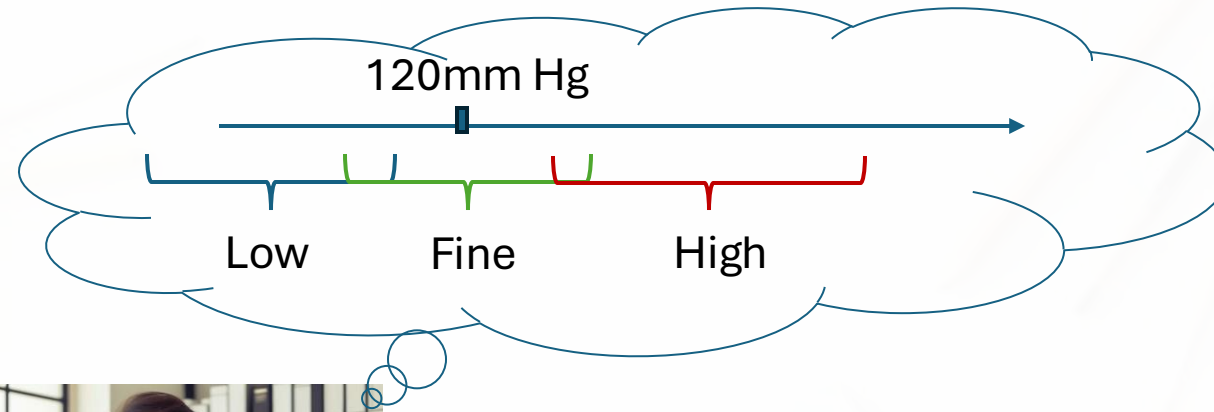
Regla Difusa

If blood pressure Low

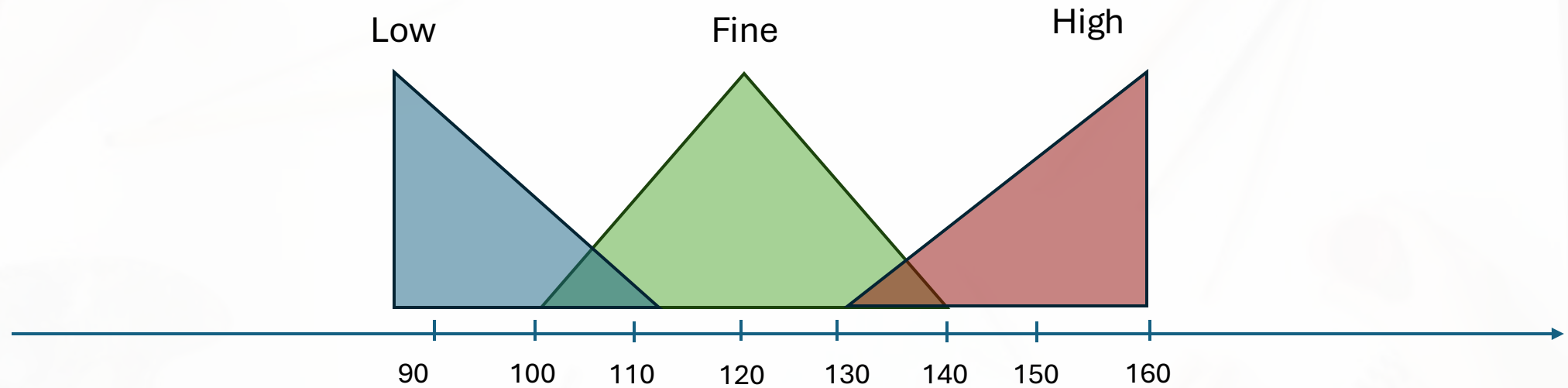


Lógica Difusa

- Las reglas difusas son un tipo particular de reglas muy útiles debido a cómo dividen el estado de entrada.



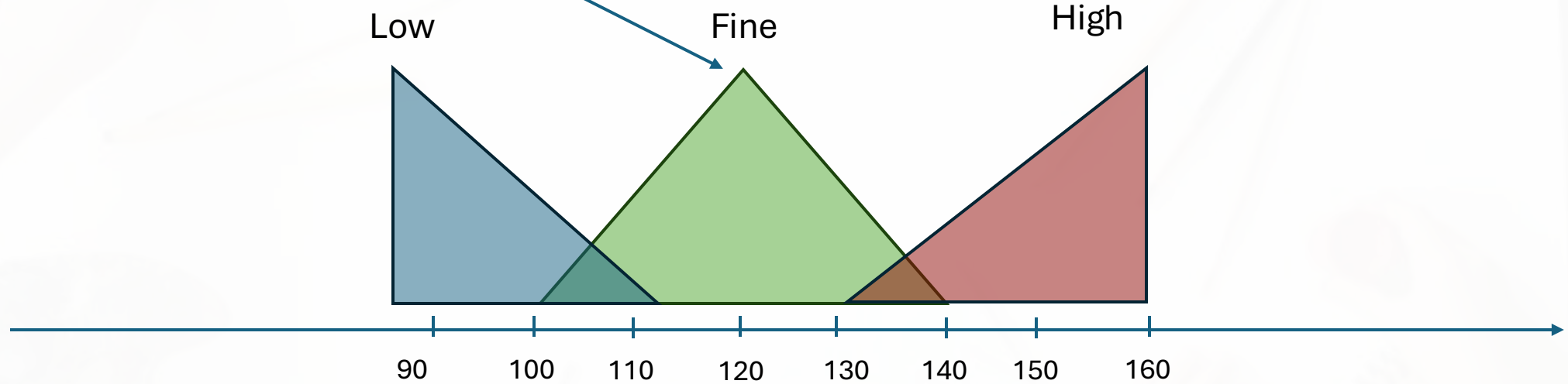
Particiones Difusas



Particiones Difusas

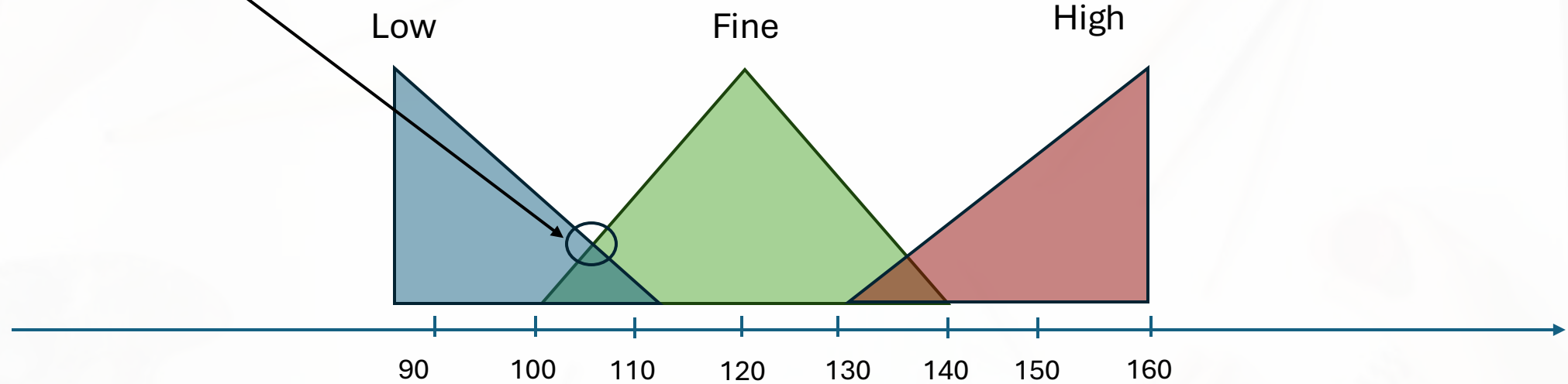
120mm Hg

(Equivalente a la lógica clásica en este caso)

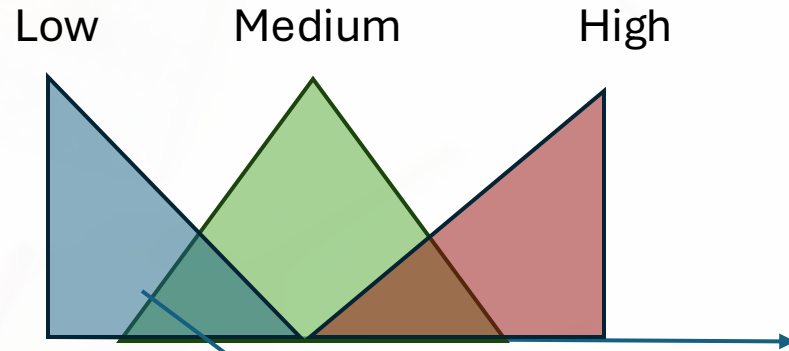


Particiones Difusas

105mm Hg



Razonamiento con reglas



Rules for consequent: setosa

IF petal width (cm) IS Low WITH DS 0.7359951780154956, ACC 0.9444444444444444

Rules for consequent: versicolor

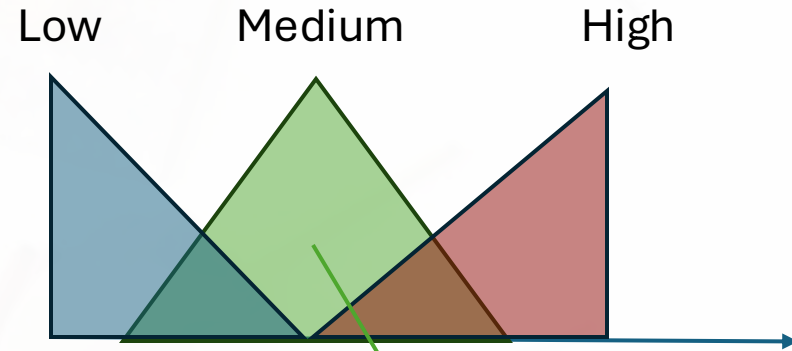
IF petal width (cm) IS Medium WITH DS 0.7630571825431511, ACC 0.90625

Rules for consequent: virginica

IF sepal length (cm) IS High AND petal width (cm) IS High WITH DS 0.5742697564048905, ACC 0.9354838709677419

IF sepal length (cm) IS Low AND petal length (cm) IS High WITH DS 0.005588278153979678, ACC 1.0

Razonamiento con Reglas



Rules for consequent: setosa

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exFuzzy

- Python
- Simplicidad para los pipelines Scikit-Learn.
- Facilidad de visualización y reporte de resultados.
- FOCO en la EXPLICABILIDAD (especialmente en la forma de aprender las reglas)
- Para los entusiastas: soporte para diferentes tipos de conjuntos difusos, conjuntos difusos automatizados o precalculados, coberturas lingüísticas, etc.

Inferencia difusa clásica

- Calcular el nivel de verdad de cada regla
 - Los operadores lógicos clásicos son sustituidos por funciones. Por ejemplo, la conjunción es el producto.
- Se asigna un peso a cada regla.
- A cada ejemplo se le asigna la clase de la regla con un mayor nivel de verdad y peso.
 - Hay otras alternativas que utilizan diversas reglas para clasificar, pero se ha elegido esta opción para que la interpretación sea más sencilla.

Entrenando un clasificador con exFuzzy

- Seleccionamos los parámetros:
 - Máximo número de reglas
 - Máximo número de variables en el antecedente
 - Número de etiquetas en la partición difusa
 - Tipo de conjunto difuso (t_1 , t_2)

Entrenando un clasificador con exFuzzy

- Optimización genética:
 - Establecemos el número de generaciones y el número de individuos.
 - Ajuste mediante el coeficiente de correlación de Matthew.
 - Aunque hay posibilidad de cambiar esta función

$$MCC = \frac{(TP \times TN) - (FP \times FN)}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}}$$

pymoo

Entrenando un clasificador con exFuzzy

- Código (No hay variables lingüísticas precalculadas, se optimizan con el resto de las reglas).

```
import ex_fuzzy.fuzzy_sets as fs
import ex_fuzzy.evolutionary_fit as GA
import ex_fuzzy.utils as utils
import ex_fuzzy.eval_tools as eval_tools

iris = datasets.load_iris()
X = pd.DataFrame(iris.data, columns=iris.feature_names)
y = iris.target

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33, random_state=0)
fl_classifier = GA.BaseFuzzyRulesClassifier(nRules=10, nAnts=4, n_linguist_variables=3,
                                           fuzzy_type=fs.FUZZY_SETS.t2, tolerance=0.001)
fl_classifier.fit(X_train, y_train, n_gen=50, pop_size=30)

eval_tools.eval_fuzzy_model(fl_classifier, X_train, y_train, X_test, y_test,
                           plot_rules=True, print_rules=True, plot_partitions=True)
```


Entrenando un clasificador con exFuzzy

- Código:

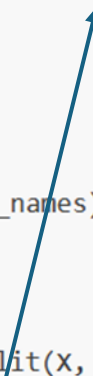
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Número máximo de reglas



Entrenando un clasificador con exFuzzy

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```

Número máximo de condiciones en el antecedente



Entrenando un clasificador con exFuzzy

- Código:


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```

Número de particiones en variables numéricas



Entrenando un clasificador con exFuzzy

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eval_tools.eval_fuzzy_model(fl_classifier, X_train, y_train, X_test, y_test,
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```

Tipo de conjunto difuso



Entrenando un clasificador con exFuzzy

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```

Módulo de evaluación



Visualizando las reglas resultantes

- El algoritmo te devuelve la base de reglas obtenida:
 - También se obtiene la dominancia/precisión de cada regla

```
-----  
Rules for consequent: setosa  
-----  
IF petal width (cm) IS Low WITH DS 0.7359951780154956, ACC 0.9444444444444444  
  
Rules for consequent: versicolor  
-----  
IF petal width (cm) IS Medium WITH DS 0.7630571825431511, ACC 0.90625  
  
Rules for consequent: virginica  
-----  
IF sepal length (cm) IS High AND petal width (cm) IS High WITH DS 0.5742697564048905, ACC 0.9354838709677419  
IF sepal length (cm) IS Low AND petal length (cm) IS High WITH DS 0.005588278153979678, ACC 1.0
```

Reglas fáciles de entender y guardar

```
-----  
Rules for consequent: setosa  
-----  
IF petal width (cm) IS Low WITH DS 0.7359951780154956, ACC 0.9444444444444444  
  
Rules for consequent: versicolor  
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IF sepal length (cm) IS Low AND petal length (cm) IS High WITH DS 0.005588278153979678, ACC 1.0
```

```
# Load rules from a plain text file  
with open('iris_rules.txt', 'r') as f:  
    str_rules = f.read()  
  
# Persistence of the rules example  
mrule_base = persistence.load_fuzzy_rules(str_rules, precomputed_partitions)  
  
fl_classifier2 = GA.BaseFuzzyRulesClassifier(precomputed_rules=mrule_base)  
# fl_classifier2.load_master_rule_base(mrule_base) # (Another possibility)
```



File

Rules in text
format



Exportar resultados para artículos

- Soporta tablas de latex

Author	Antecedents	DS	Train Acc	Test Acc
	1 IF New Realism IS Low AND Post Impressionism IS Medium	0.0076	0.5000	0.0000
	2 IF Early Renaissance IS Medium AND New Realism IS Medium AND Synthetic Cubism IS Medium	0.0740	0.7777	1.0000
	3 IF Early Renaissance IS Low AND Synthetic Cubism IS High	0.2517	0.9390	0.8888
	4 IF Synthetic Cubism IS Low	0.4624	0.9097	0.9250
	5 IF Contemporary Realism IS Medium AND Synthetic Cubism IS Low AND Relevant area IS Low	0.0092	0.0000	0.0000
	6 IF Contemporary Realism IS Medium AND Minimalism IS Low	0.3389	0.7586	0.7692
	7 IF Early Renaissance IS Medium AND Minimalism IS Medium AND Synthetic Cubism IS Medium	0.0124	0.0000	0.0000

Fumanal-Idocin, J., Andreu-Perez, J., Cord, O., Hagraas, H., & Bustince, H. (2023). Artxai: Explainable artificial intelligence curates deep representation learning for artistic images using fuzzy techniques. *IEEE Transactions on Fuzzy Systems*.

¿Porqué exFuzzy?

- Librerías "difusas":



(Python)

- Scikit-fuzzy, Simpy



(Java)

- Juzzy (many more)



(MATLAB)

- Fuzzy logic toolbox



(R)

- Lfl



(Julia)

- FuzzyLogic.jl, fuzzy.jl

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Sin módulos de aprendizaje

Solo ANFIS

Requiere familiaridad con la teoría de la lógica difusa



<https://github.com/Fuminides/ex-fuzzy>

Instalar exFuzzy

- Desde pypi: `pip install ex-fuzzy`
- Desde github:
 - > `git clone https://github.com/Fuminides/ex-fuzzy.git`
 - > `cd ex-fuzzy`
 - > `pip install .`



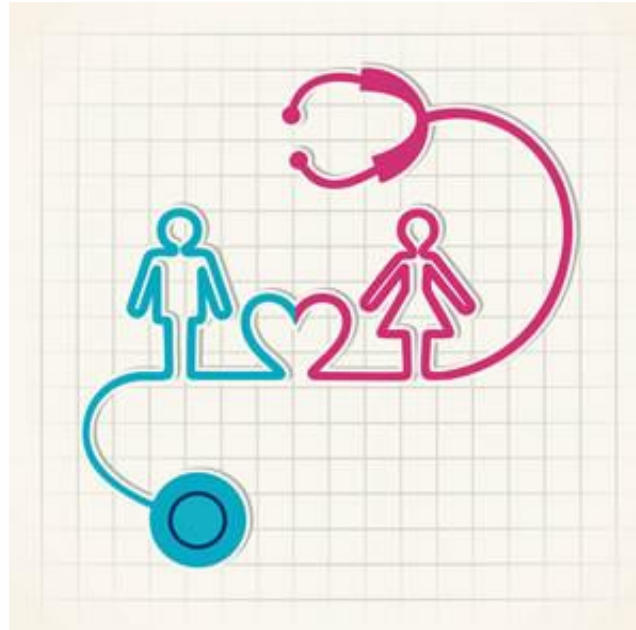
Tutorial: Detección y mitigación de sesgos con exFuzzy

<https://github.com/Fuminides/WorkshopIgualdad2025>

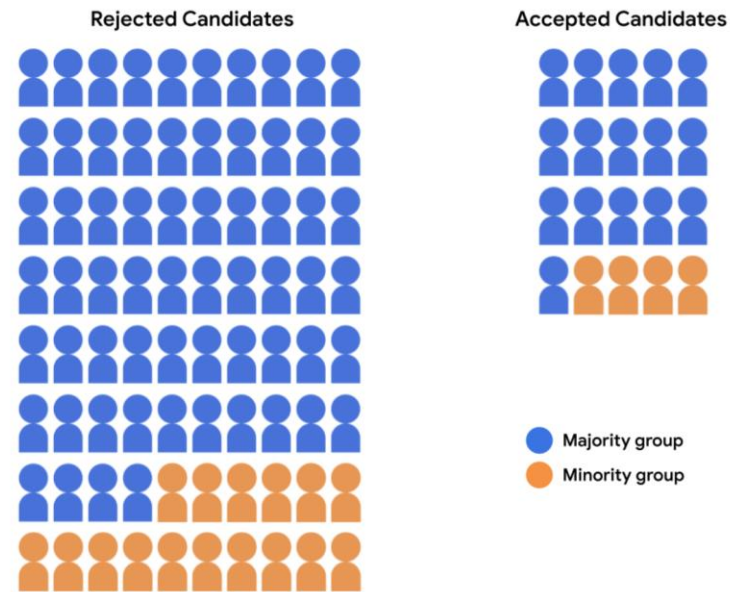
Ejemplo 1 - Titanic



Ejemplo 2 – Supervivencia a fallo cardiaco



Ejemplo 3 – Concesión de préstamos





Resumen Final

En este workshop hemos visto...

- Como los algoritmos de XAI nos pueden ayudar a identificar posibles sesgos en nuestros resultados.
- Introducción a la librería exFuzzy como un recurso más para entrenar clasificadores basados en reglas, los cuales son interpretables.
- Algunas técnicas sencillas para mitigación de sesgos, que pueden utilizar conjuntamente con la librería.

Algunos proyectos futuros

- Cuantificación de incertidumbre.
-



- Descubrimiento de subgrupos
-

- Direccionalidad

¿EL HUEVO O LA GALLINA?



¡Gracias!

Universidad Carlos III, Madrid, 2025



Lee la documentación!

<https://fuminides.github.io/ex-fuzzy/>



Usa el código!

<https://github.com/Fuminides/ex-fuzzy>



ELSEVIER

Cita el artículo!

<https://www.sciencedirect.com/science/article/pii/S0925231224008191>



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