Biometrics

COMP 388-002/488-002 Computer Science Topics

Daniel Moreira

Fall 2025

LOYOLA UNIVERSITY CHICAGO

Welcome

COMP 388-002/488-002 Computer Science Topics
Biometrics

Daniel Moreira
Contact: dmoreira1@luc.edu and Teams
Office: Doyle Center 310

Course Hours
Lectures: MON and WED, 4:15 to 5:30 PM, Information Commons 112
Office Hours: TUE evenings and FRI mornings
Doyle Center 310 or Zoom, by appointment (https://tinyurl.com/yv76kjpb)

Communication
Sakai: https://sakai.luc.edu/x/wYe0XI
Webpage: https://danielmoreira.github.io/teaching/biometrics-aut25/

LOYOLA UNIVERSITY CHICAGO

Today we will…

Get to know what is ahead of you
in the course.

About me

Computer Scientist
PhD from the University of Campinas (Brazil)
Theme: Sensitive-Video Analysis

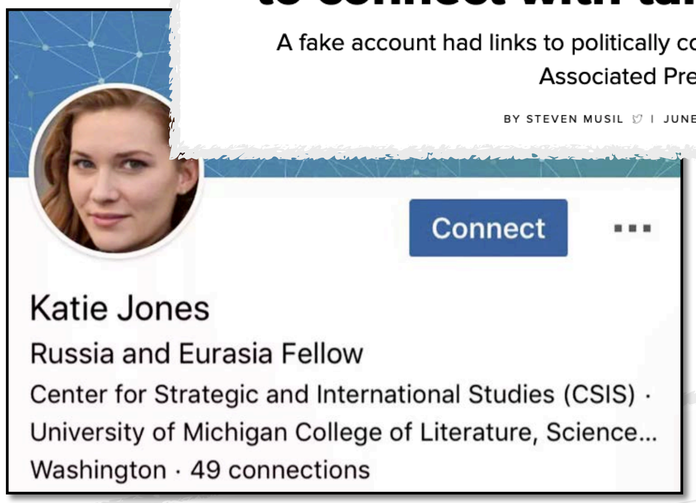
Loyola University Chicago
Assistant Professor
Joined on August 15, 2022

Research
Media Forensics, Biometrics, Machine Learning, Computer Vision
Webpage: https://danielmoreira.github.io
(see following slides)

LOYOLA UNIVERSITY CHICAGO


Media Forensics
https://danielmoreira.github.io/project/medifor/

The Problem



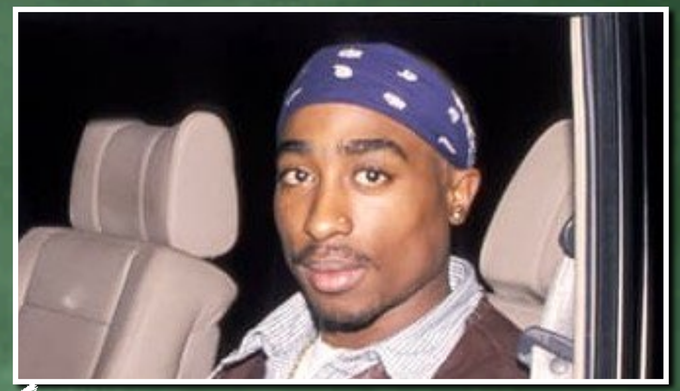
https://www.youtube.com/watch?v=p7-B8S734T4

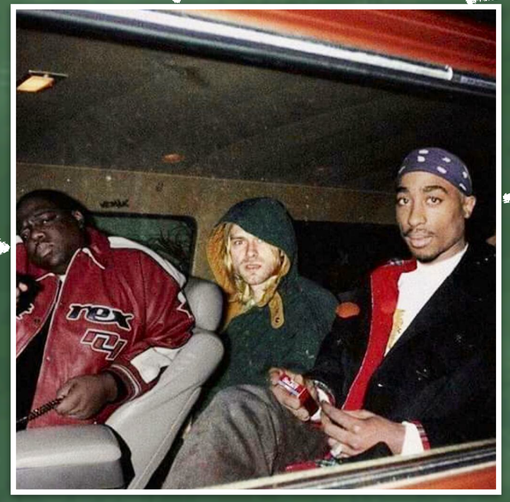
LOYOLA UNIVERSITY CHICAGO


The Notorious B.I.G.
NY scene rapper
HANGING OUT?
Kurt Cobain
Grunge scene musician

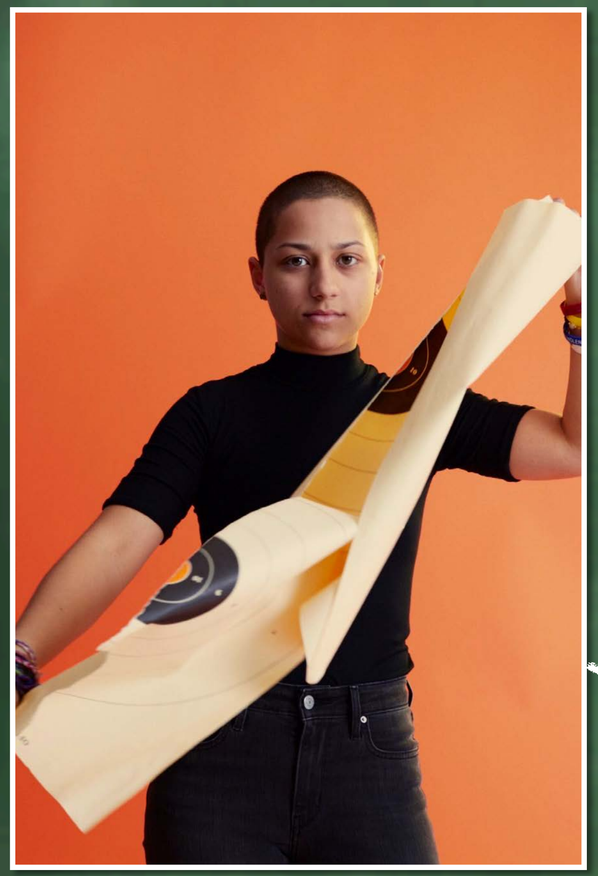

rex

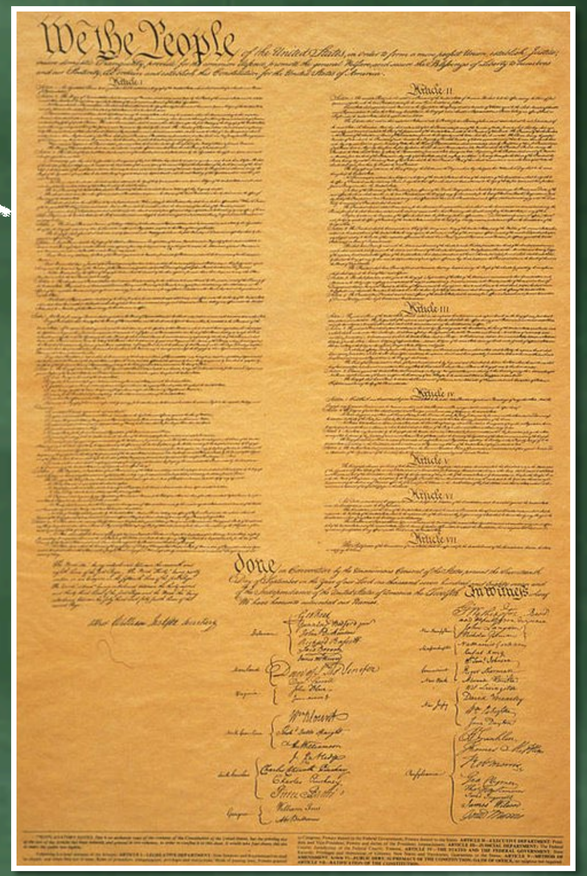

Tupac Shakur
LA scene rapper



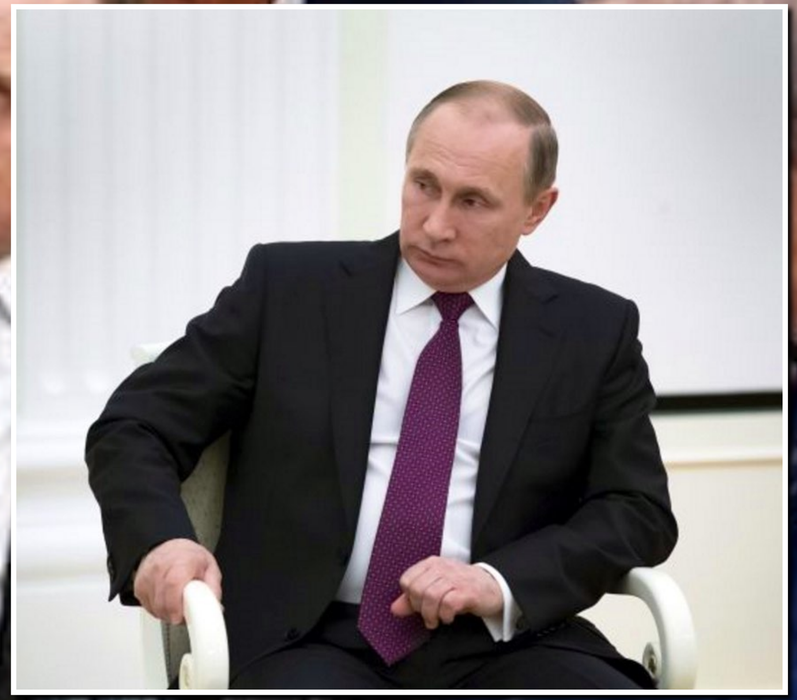


Provenance Graph






Russian Federation
Turkey



Russian Federation

Turkey

Scientific Integrity

https://danielmoreira.github.io/project/sciint/

The Problem

nature

Retraction Note | Published: 15 April 2015

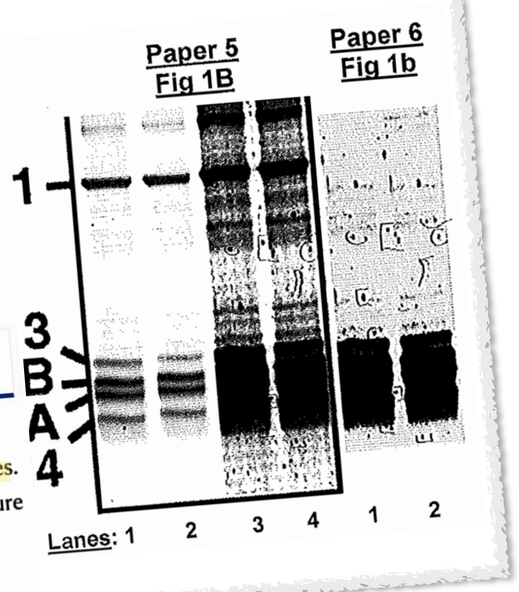
Retraction Note: Histone methylation by the *Drosophila* epigenetic transcriptional regulator Ash1

Nature **521**, 110 (2015) | Cite this article

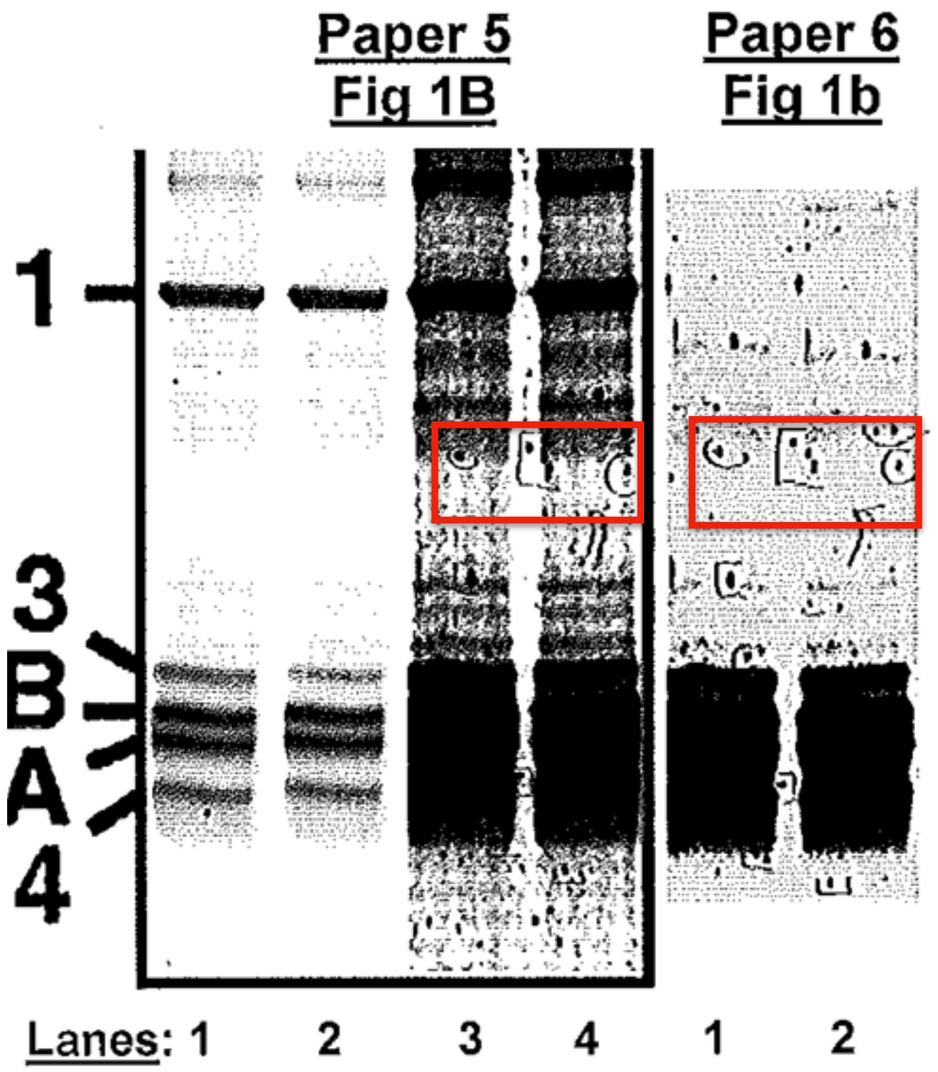
27k Accesses | **34** Altmetric | Metrics

The Original Article was published on 09 October 2002

The authors and the University of [redacted] wish to retract this Letter owing to inappropriate image manipulation in the published figures. The figure panels affected are Figure 1b, d, Figure 2b, e, Figure 3a and Figure 4d. *Nature* has not received a response from [redacted] to approve this retraction.



LOYOLA UNIVERSITY CHICAGO



CORRECTIONS & AMENDMENTS

RETRACTION

doi:10.1038/nature14421

Retraction: Histone methylation by the *Drosophila* epigenetic transcriptional regulator Ash1

[redacted]

Nature **419,** 857–862 (2002); doi:10.1038/nature01126

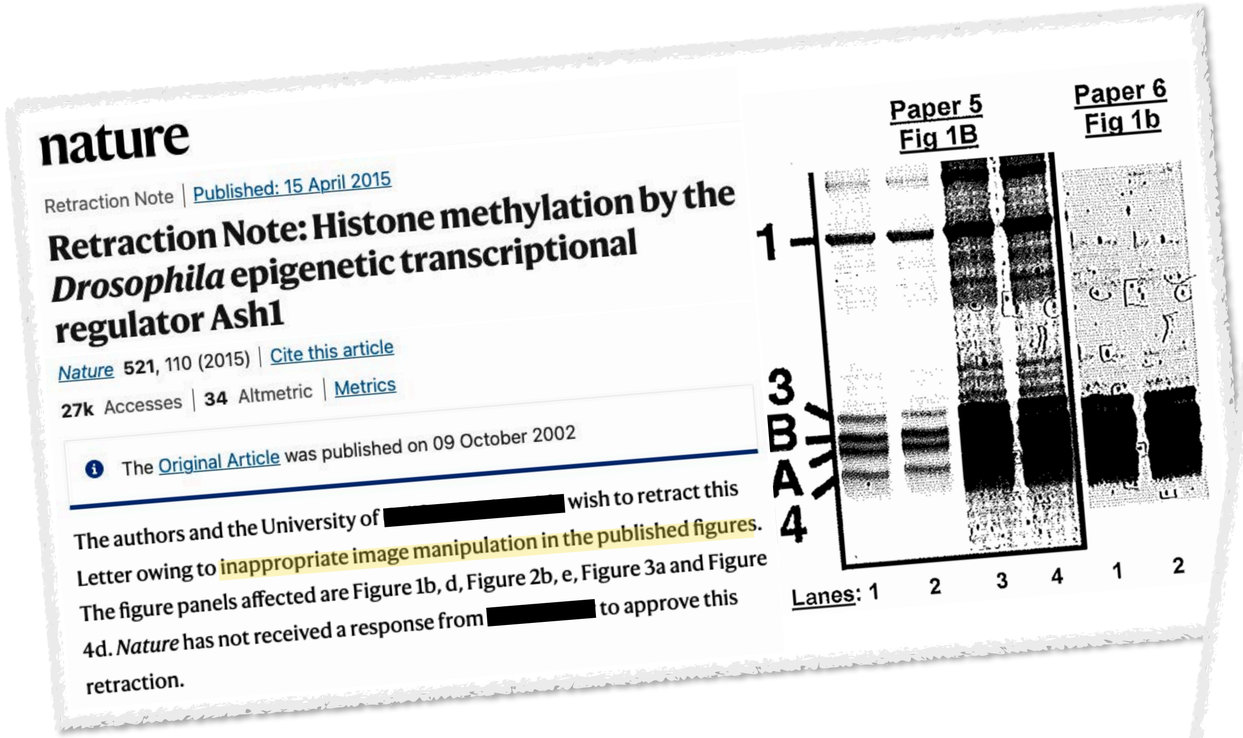
The authors and the University of [redacted] wish to retract this Letter owing to inappropriate image manipulation in the published figures. The figure panels affected are Figure 1b, d, Figure 2b, e, Figure 3a and Figure 4d. *Nature* has not received a response from [redacted] to approve this retraction.

Additional information

The online version of the original article can be found at 10.1038/nature01126

LOYOLA UNIVERSITY CHICAGO

The Problem



nature

Retraction Note | Published: 15 April 2015

Retraction Note: Histone methylation by the *Drosophila* epigenetic transcriptional regulator Ash1

Nature **521**, 110 (2015) | Cite this article

27k Accesses | **34** Altmetric | Metrics

The Original Article was published on 09 October 2002

The authors and the University of [redacted] wish to retract this Letter owing to inappropriate image manipulation in the published figures. The figure panels affected are Figure 1b, d, Figure 2b, e, Figure 3a and Figure 4d. *Nature* has not received a response from [redacted] to approve this retraction.

Paper 5 Fig 1B

Paper 6 Fig 1b

1
3
B
A
4

Lanes: 1 2 3 4 1 2

HEALTH

SEC Investigating Cassava Sciences, Developer of Experimental Alzheimer's Drug

Cassava, one of best-performing U.S. stocks this year, denies claims that it manipulated research results

THE WALL STREET JOURNAL.

By Dave Michaels and Joseph Walker

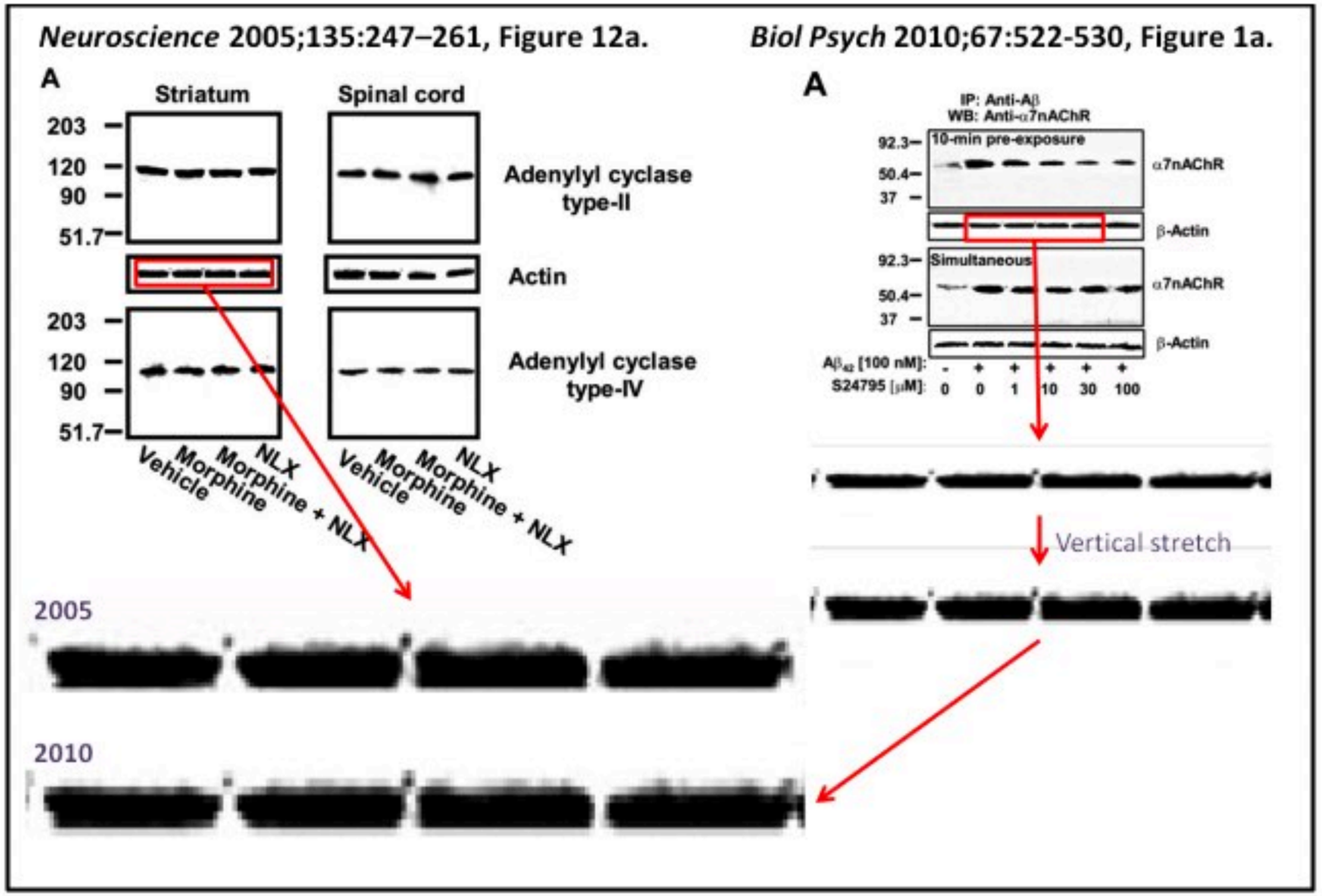
Updated Nov. 17, 2021 4:55 pm ET

Neuroscience 2005;135:247–261, Figure 12a.

Biol Psych 2010;67:522-530, Figure 1a.

Striatum
Spinal cord
Adenylyl cyclase type-II
Actin
Adenylyl cyclase type-IV
Vehicle
Morphine
NLX
Morphine + NLX
2005
2010
Vertical stretch

LOYOLA UNIVERSITY CHICAGO



HEALTH

SEC Investigating Cassava Sciences, Developer of Experimental Alzheimer's Drug

Cassava, one of best-performing U.S. stocks this year, denies claims that it manipulated research results

THE WALL STREET JOURNAL.

By Dave Michaels and Joseph Walker

Updated Nov. 17, 2021 4:55 pm ET

LOYOLA UNIVERSITY CHICAGO

The Problem

nature

Retraction Note | Published: 15 April 2015

Retraction Note: Histone methylation by the *Drosophila* epigenetic transcriptional regulator Ash1

Nature **521**, 110 (2015) | Cite this article

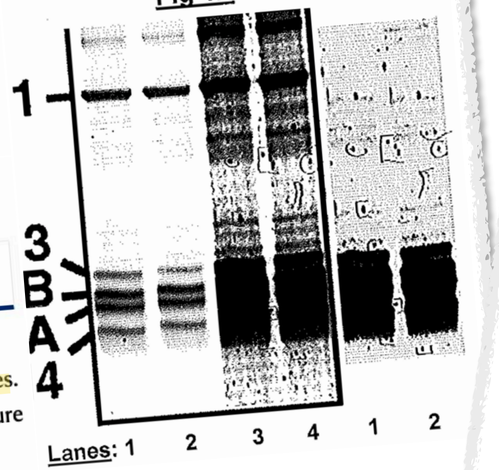
27k Accesses | **34** Altmetric | Metrics

The Original Article was published on 09 October 2002

The authors and the University of [redacted] wish to retract this Letter owing to inappropriate image manipulation in the published figures. The figure panels affected are Figure 1b, d, Figure 2b, e, Figure 3a and Figure 4d. *Nature* has not received a response from [redacted] to approve this retraction.

Paper 5 Fig 1B

Paper 6 Fig 1b



HEALTH

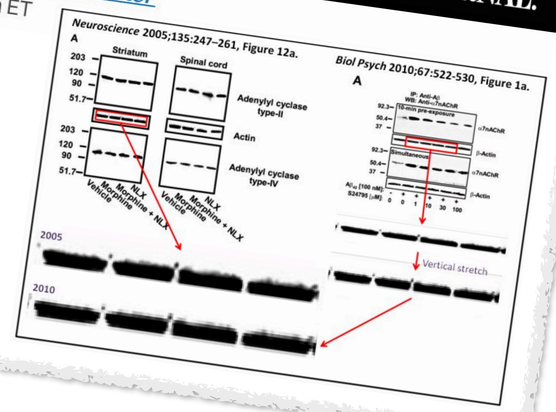
SEC Investigating Cassava Sciences, Developer of Experimental Alzheimer's Drug

Cassava, one of best-performing U.S. stocks this year, denies claims that it manipulated research results

THE WALL STREET JOURNAL.

By Dave Michaels and Joseph Walker

Updated Nov. 17, 2021 4:55 pm ET

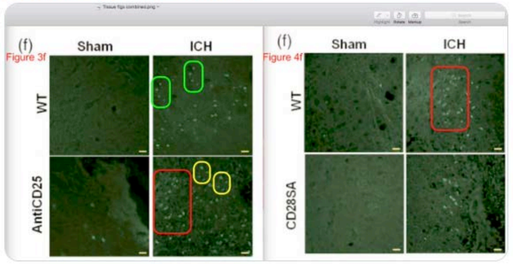


Elisabeth Bik
@MicrobiomDigest

Retraction of a paper by authors of The Third Military Medical University, Zhengzhou University, and @JohnsHopkins, 5 months after posting this to @PubPeer. pubpeer.com/publications/4...

3:17 PM · Oct 2, 2022 · Twitter Web App

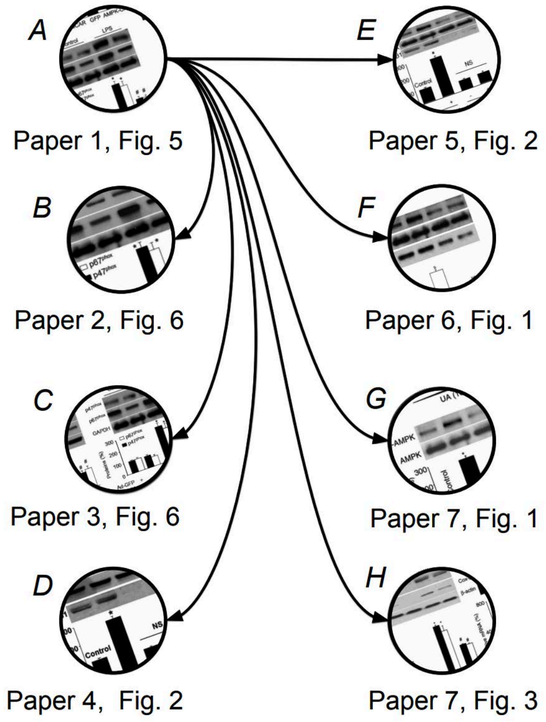
3 Retweets **41** Likes



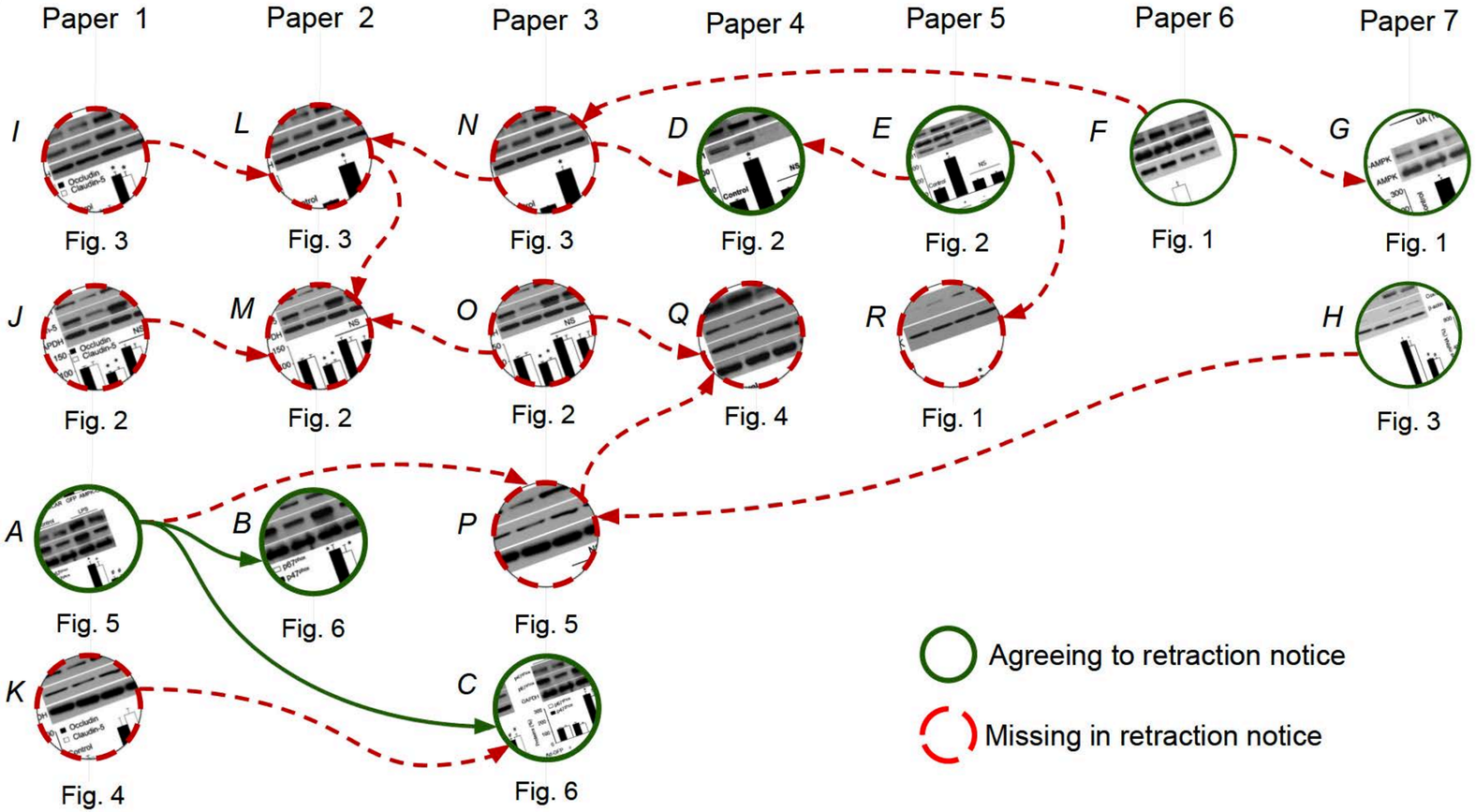
LOYOLA UNIVERSITY CHICAGO

Provenance Analysis

Ground truth
(according to retraction notice)



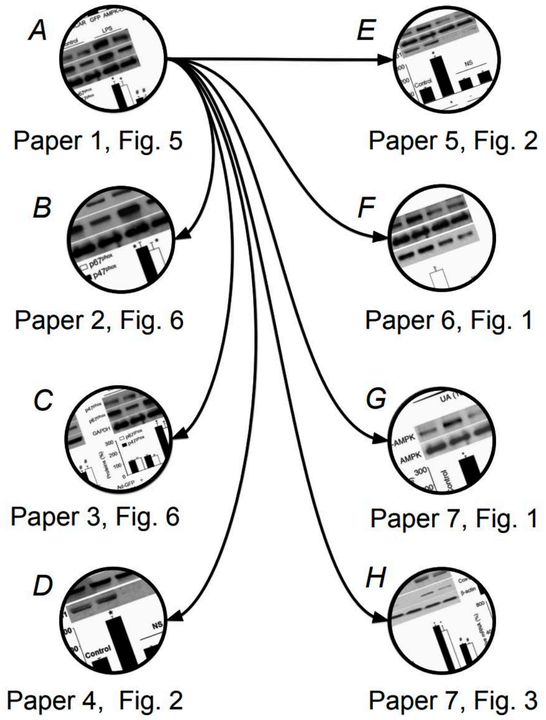
Our findings



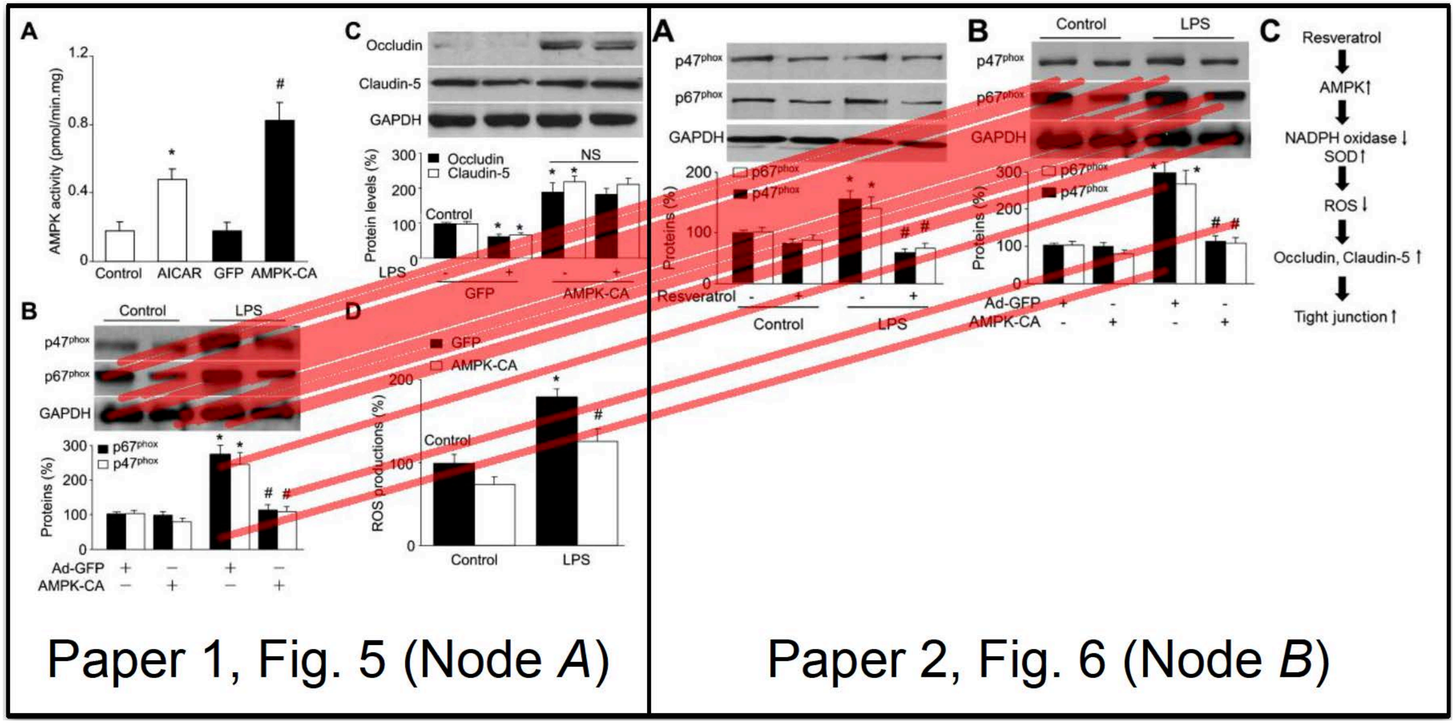
10.1371/journal.pone.0190562

Provenance Analysis

Ground truth
(according to retraction notice)



Our findings
(in accordance with retraction notice)

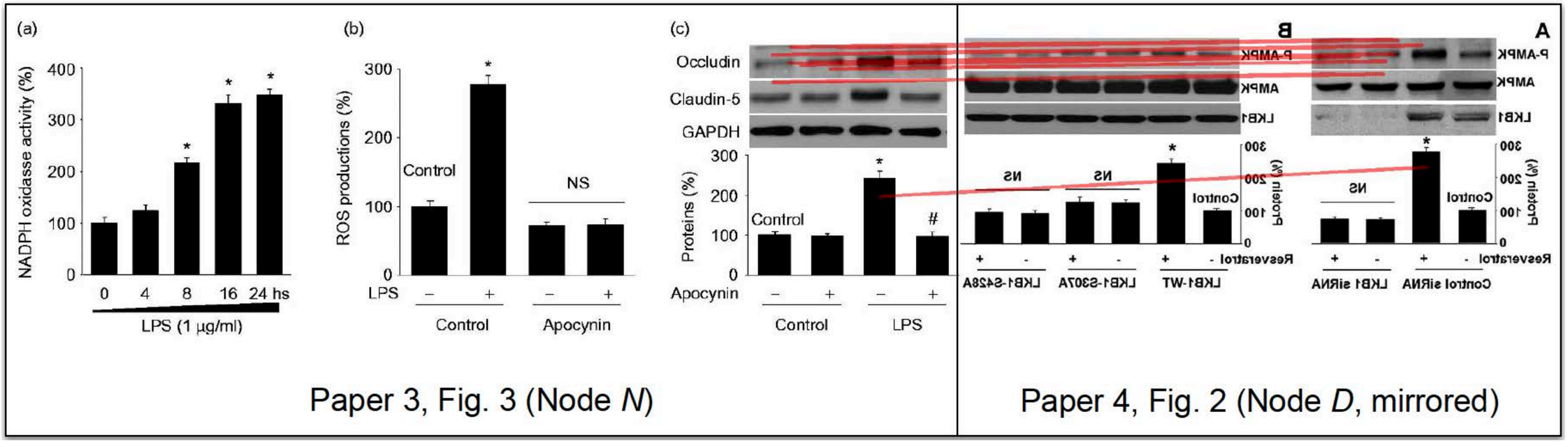


10.1371/journal.pone.0190562

LOYOLA UNIVERSITY CHICAGO

Provenance Analysis

Our findings
(not reported in the retraction notice)



Paper 3, Fig. 3 (Node *N*)

Paper 4, Fig. 2 (Node *D*, mirrored)

10.1371/journal.pone.0190562

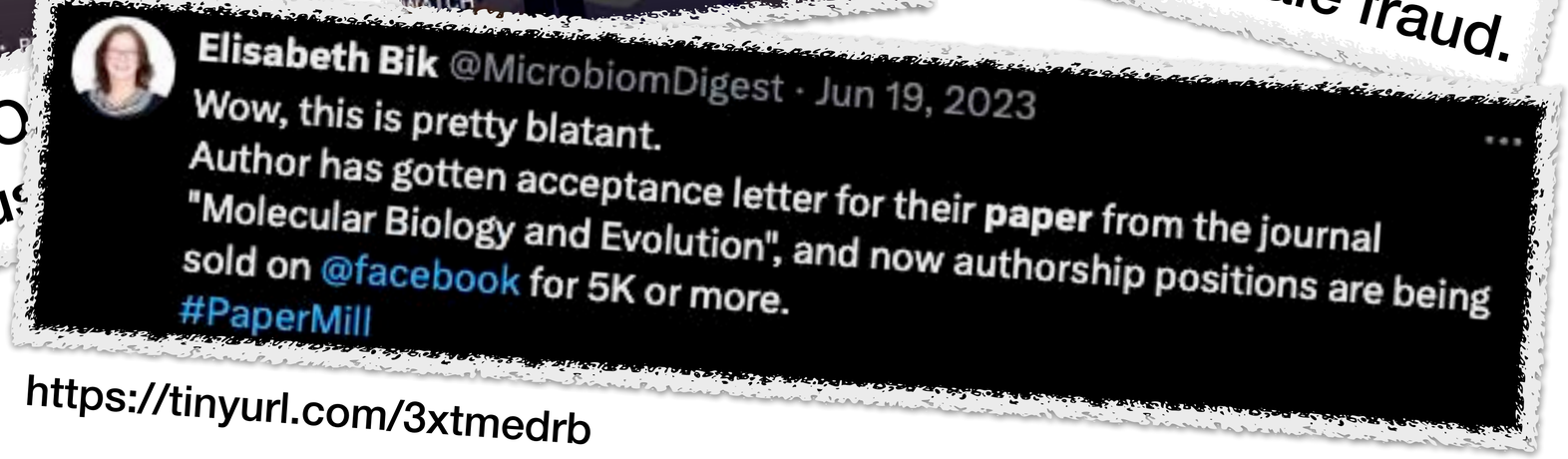
LOYOLA UNIVERSITY CHICAGO

Paper Mills

https://tinyurl.com/4ukfbka7

These are organized crime rings that are committing large-scale fraud.

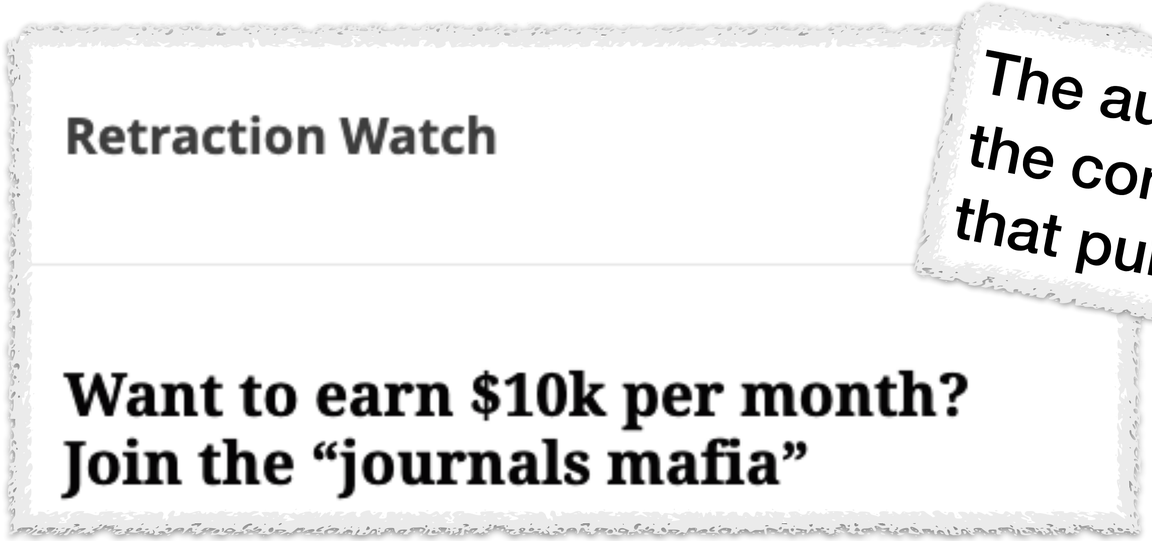
AT LEAST TENS OF MILLIO
flow to the paper mill indus



https://tinyurl.com/3xtmedrb

LOYOLA UNIVERSITY CHICAGO

Paper Mills

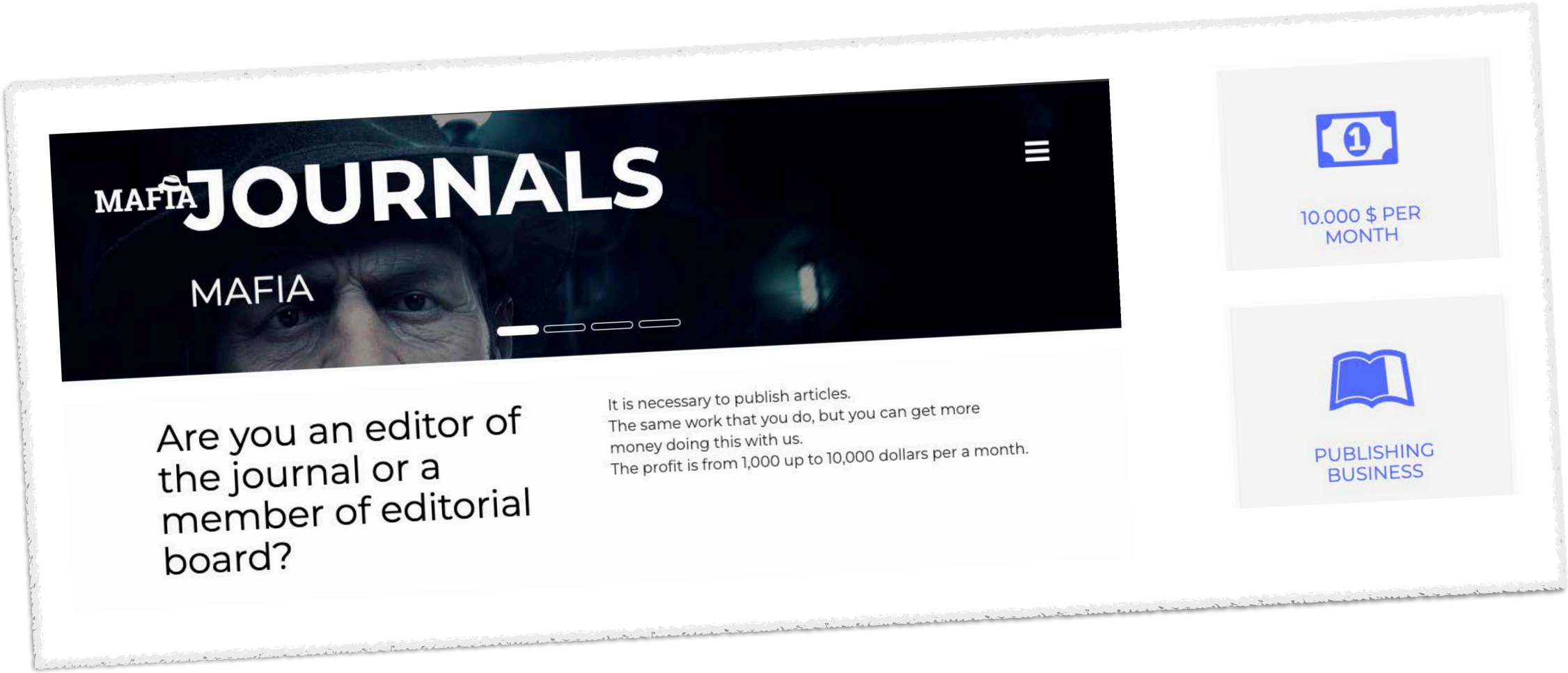

Retraction Watch

Want to earn $10k per month?
Join the “journals mafia”

The authors pay to publish the articles, the company shares the profits with journals that publish the paper.

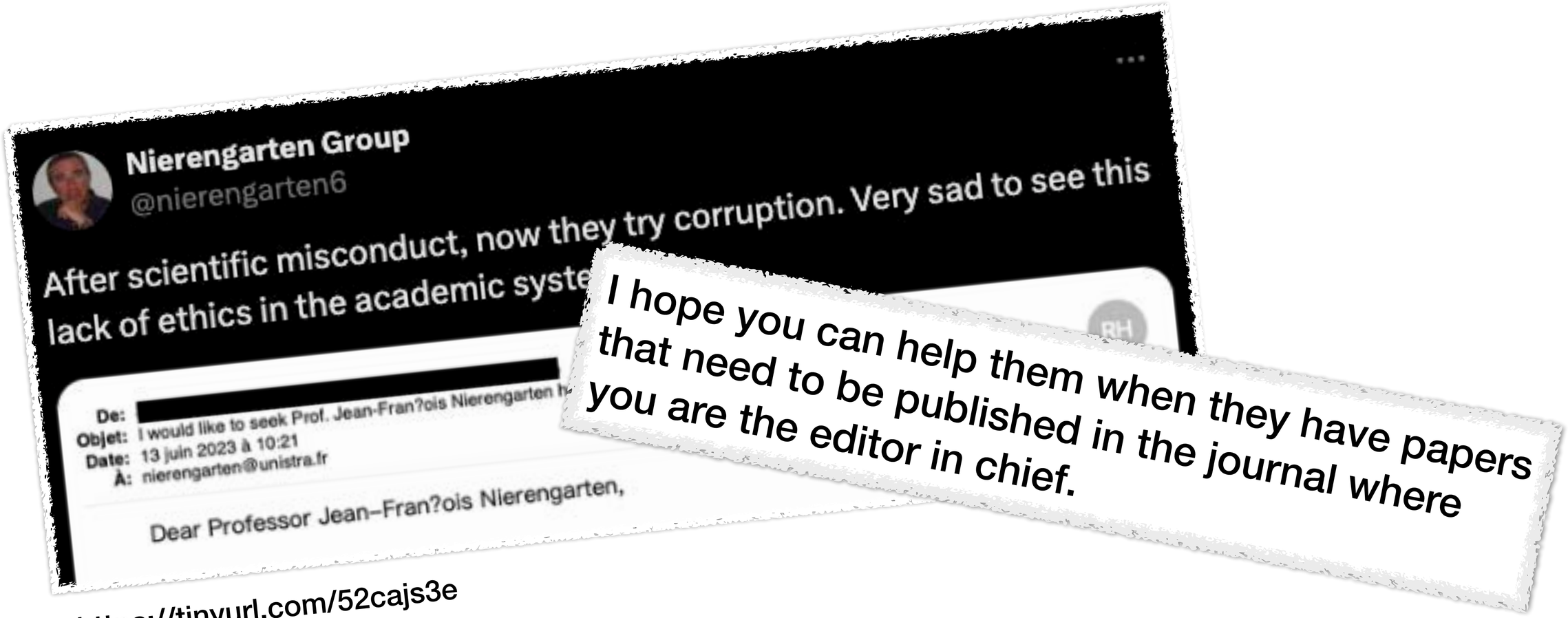
https://tinyurl.com/4m3t9umb

Paper Mills




I’m gonna make them an offer they can’t refuse.

Paper Mills



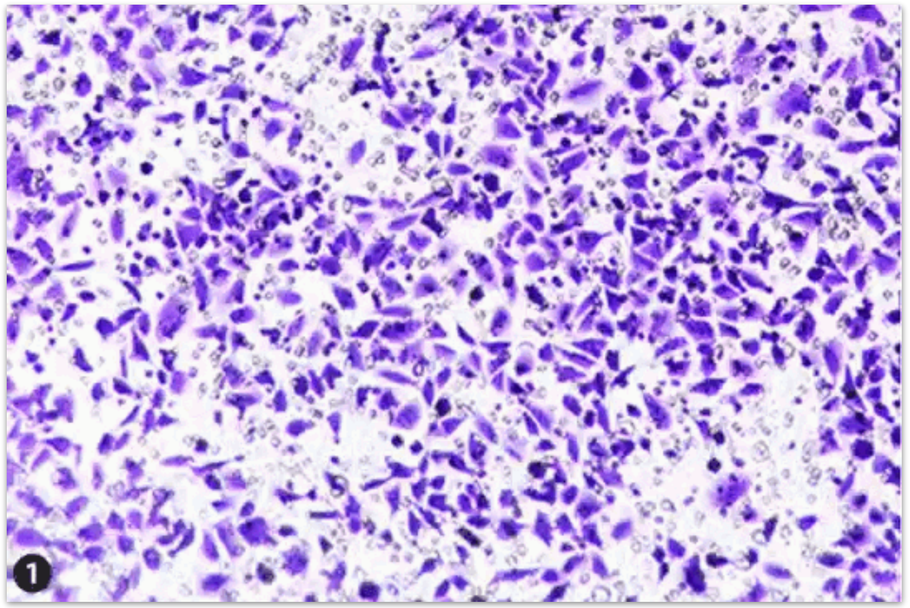
https://tinyurl.com/52cajs3e

LOYOLA UNIVERSITY CHICAGO

Paper Mills

Problems with Images?

https://tinyurl.com/2p8ecptc



https://tinyurl.com/4znhmpa6

LOYOLA UNIVERSITY CHICAGO

Paper Mills

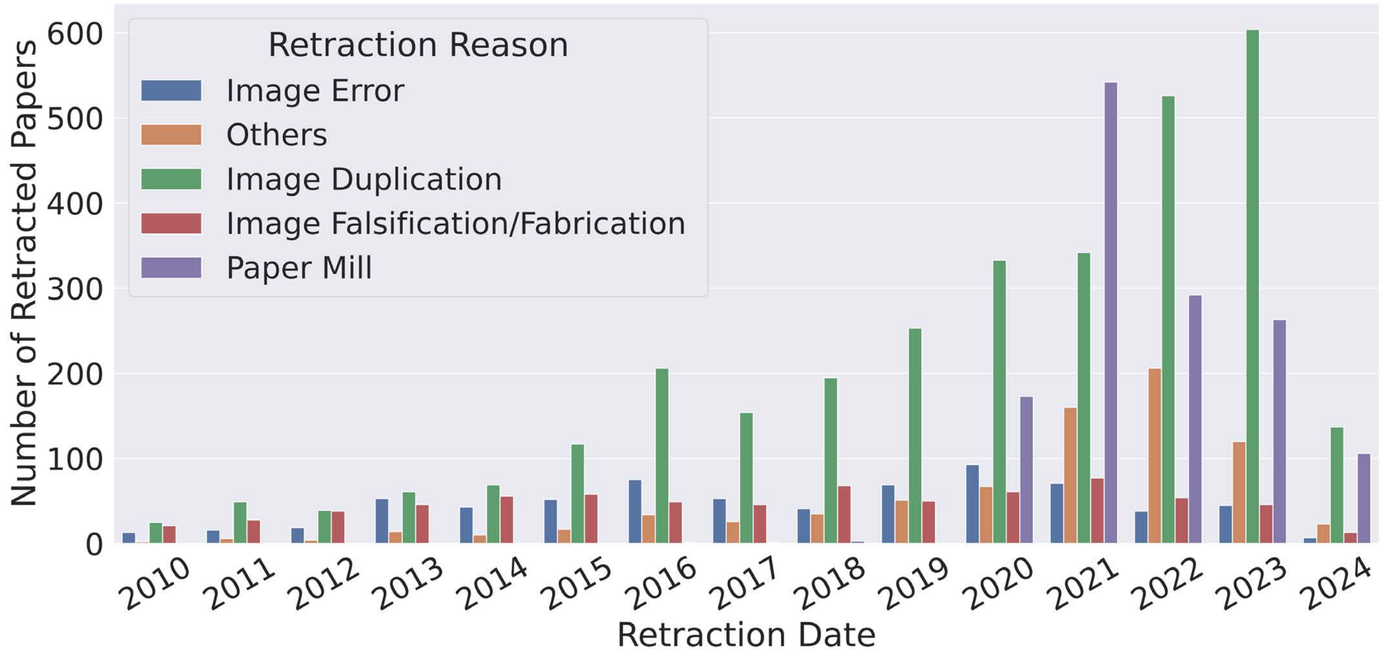
Problems with Images?

PLOS ONE

Unveiling scientific articles from paper mills with provenance analysis

Cardenuto, Moreira, and Rocha, 2024

https://tinyurl.com/2fx3p6tj



LOYOLA UNIVERSITY CHICAGO

Paper Mills

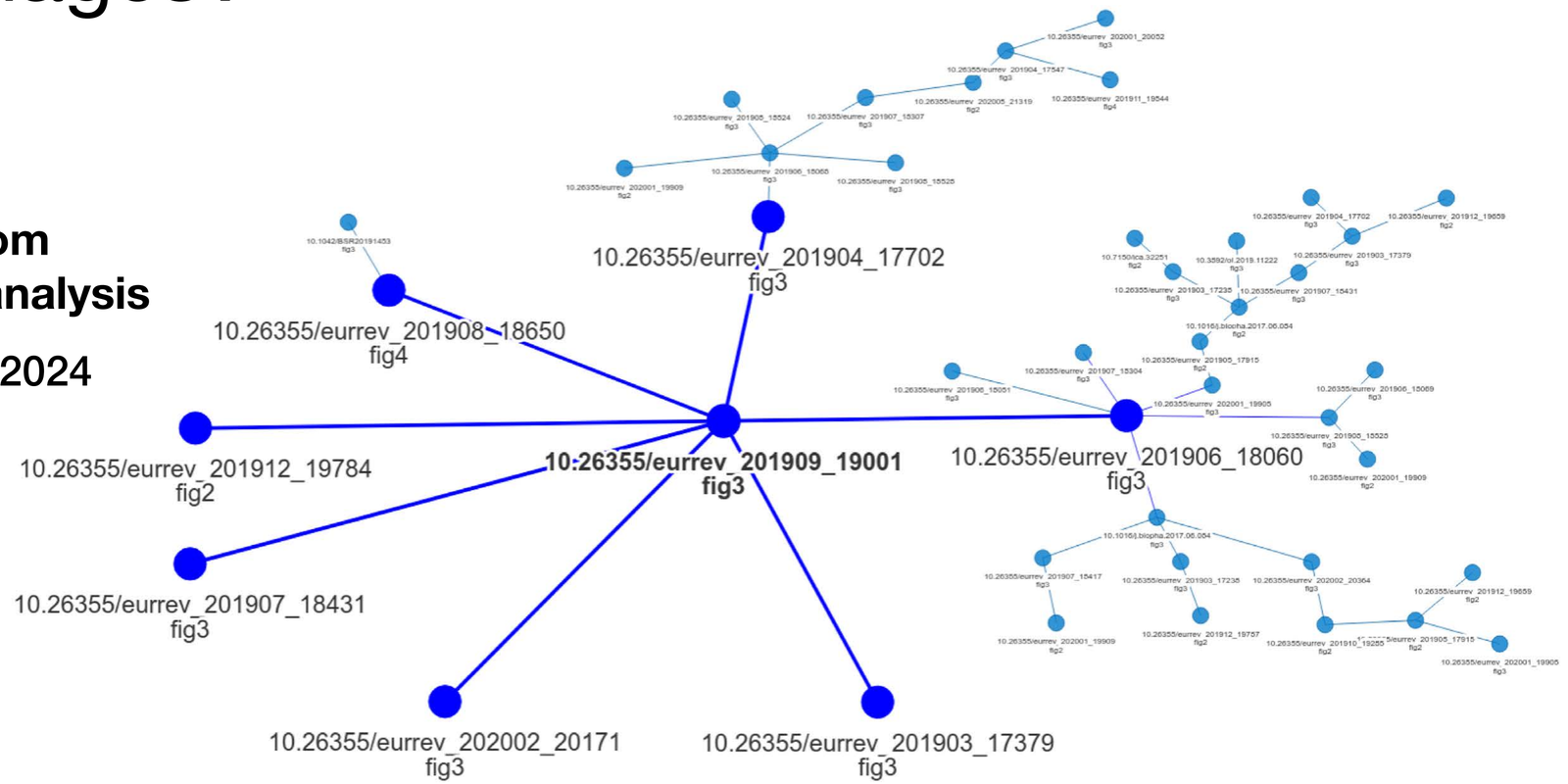
Problems with Images?

PLOS ONE

Unveiling scientific articles from paper mills with provenance analysis

Cardenuto, Moreira, and Rocha, 2024

https://tinyurl.com/2fx3p6tj



LOYOLA UNIVERSITY CHICAGO


We can use AI…

AI-generated Content

ChatGPT

DALL·E 3

Adobe Firefly

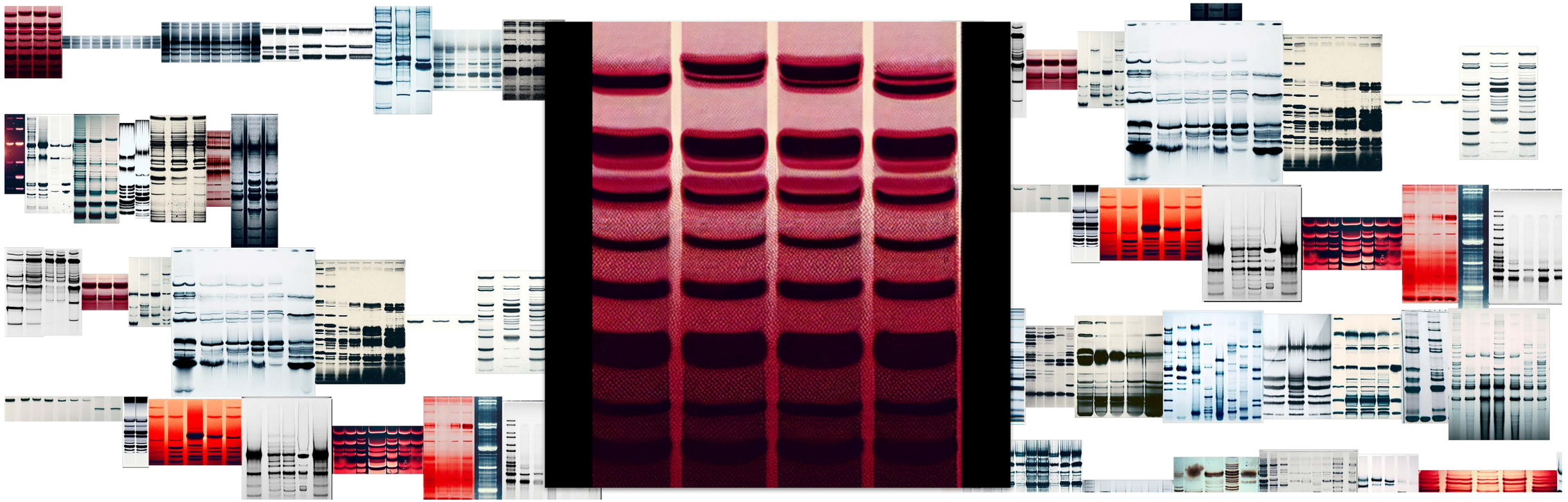
Midjourney

Hugging Face

DALL-E 3

AI-generated Content

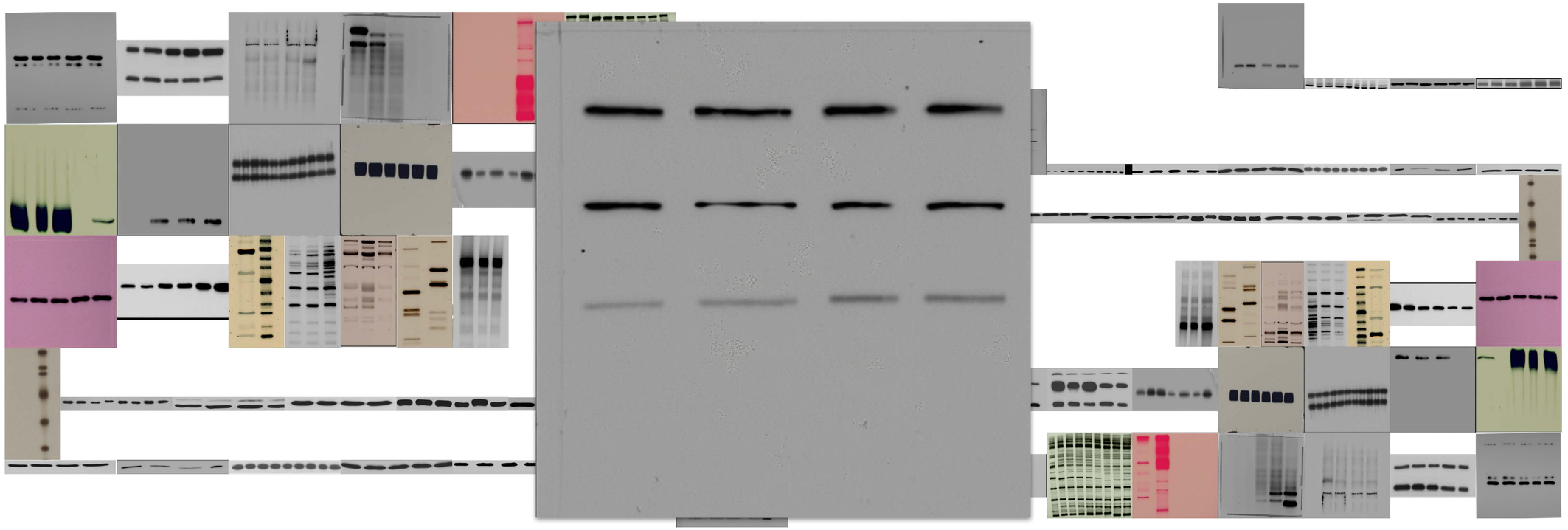
AI-generated Western blots!



DALLE-3

AI-generated Content

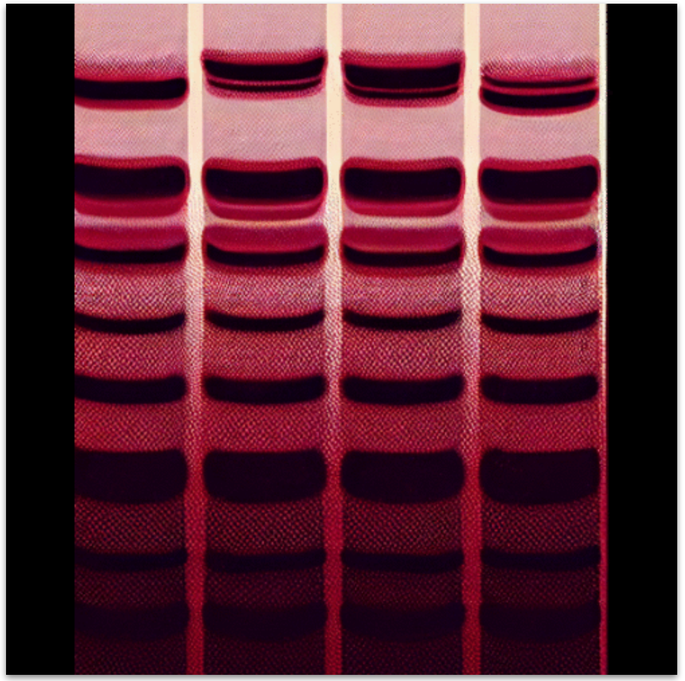
AI-generated Western blots!



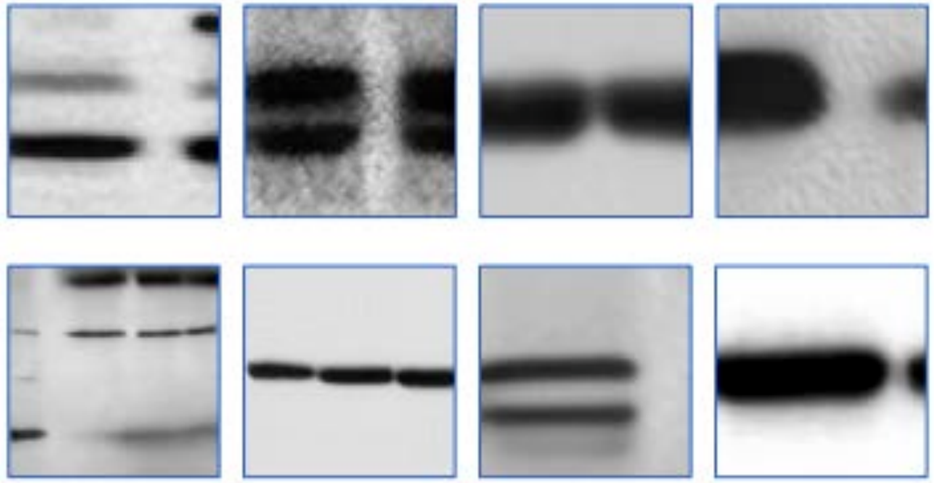
Stable Diffusion

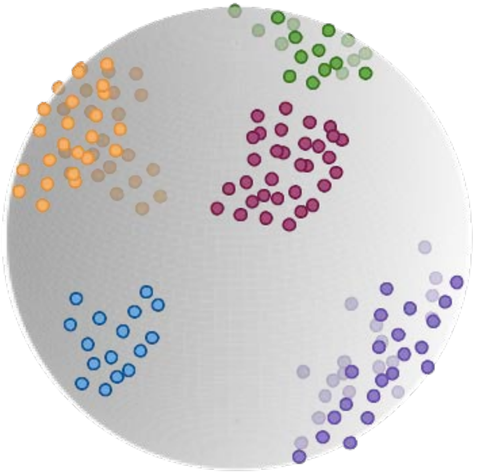
AI-generated Content

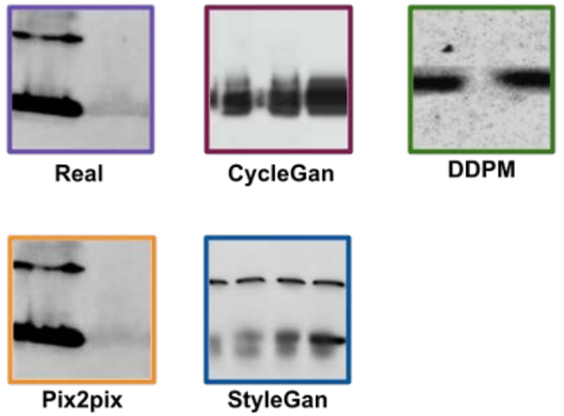
What can we do about it?



Synthetic Image Attribution







Mandelli et al.
Forensic Analysis of Synthetically Generated Western Blots
IEEE Access

IEEE WIFS 2024

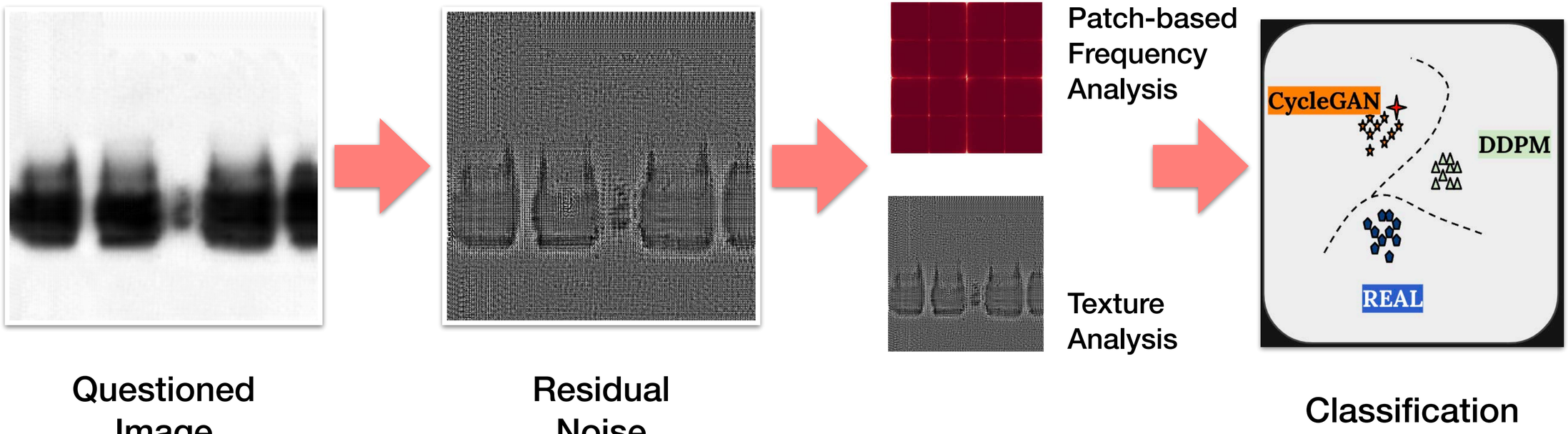
Explainable Artifacts for Synthetic Western Blot Source Attribution

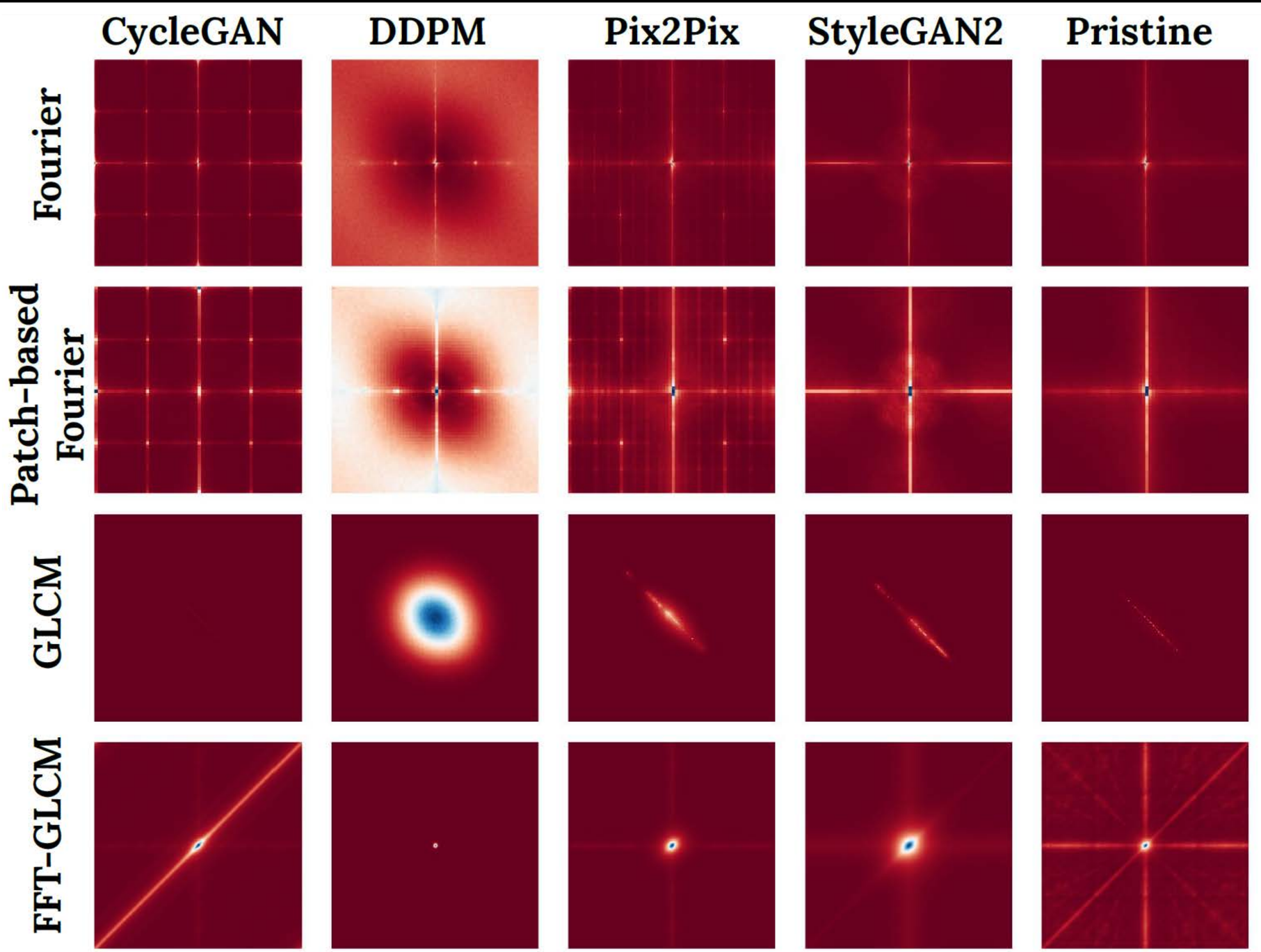
Cardenuto, Mandelli, Moreira, Bestagini, Delp, and Rocha (Unicamp, Polimi, Purdue, and LUC)

https://tinyurl.com/4fwa7syb

LOYOLA UNIVERSITY CHICAGO

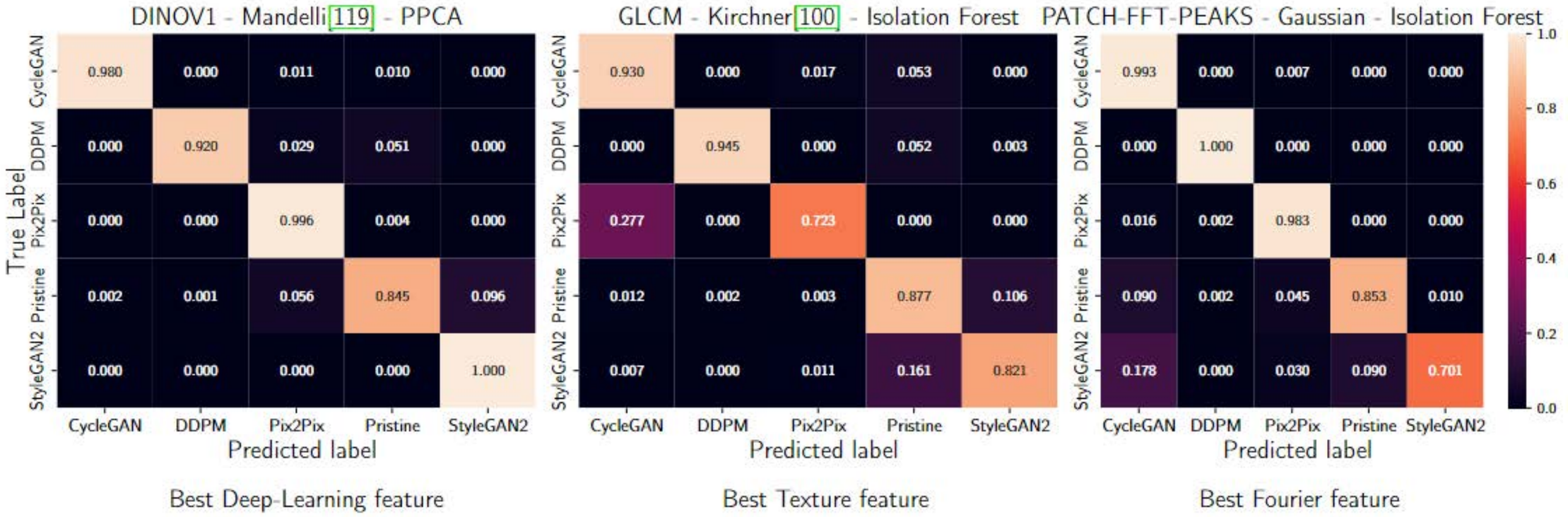
Explainable Artifacts




CycleGAN
DDPM
Pix2Pix
StyleGAN2
Pristine
Fourier
Patch-based Fourier
GLCM
FFT-GLCM

Experiments and Results

Source Attribution



Best Deep-Learning feature

Best Texture feature

Best Fourier feature

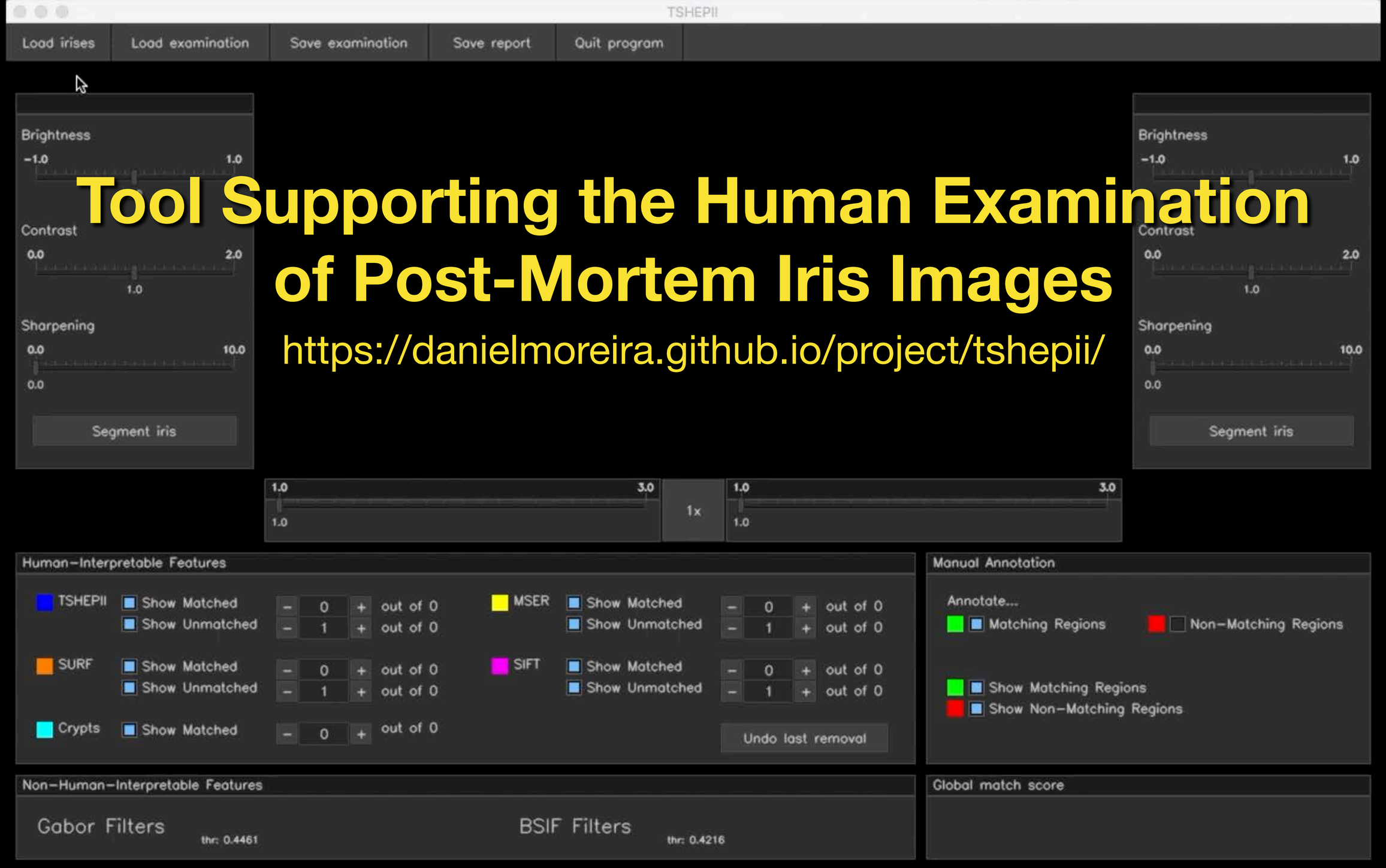
LOYOLA UNIVERSITY CHICAGO


TSHEPII
Load irises
Load examination
Save examination
Save report
Quit program
0008_R_2_1.png
Brightness
−1.0
1.0
Contrast
0.0
2.0
1.1
Sharpening
0.0
10.0
1.0
0008_R_3_1.png
Brightness
−1.0
1.0
Contrast
0.0
2.0
1.0
Sharpening
0.0
10.0
2.0
Tool Supporting the Human Examination of Post-Mortem Iris Images
https://danielmoreira.github.io/project/tshepii/
WARNING
Manual Annotation
Annotate...
out of 3
Non−Human−Interpretable Features
Gabor Filters
0.4585
impostor
genuine
9/11

The Problem

Interpretable Iris Recognition

How to convince people who do not possess image processing expertise?



Tool Supporting the Human Examination of Post-Mortem Iris Images

https://danielmoreira.github.io/project/tshepii/

How about you?

Background
9 graduate and 15 undergraduate students

What is your major?

forms.gle/
wMNBSY2NwV5LHSbo9

LOYOLA UNIVERSITY CHICAGO

How about you?

Expectations
Given your (future) career, what are your course expectations?

forms.gle/
wMNBSY2NwV5LHSbo9

How about you?

Accommodation Needs
Please reach out to me in private ASAP.
We'll make things work.

Today's Attendance

Please fill out the form

forms.gle/wMNBSY2NwV5LHSbo9

About the topic

Biometrics
What comes to your mind?

forms.gle/
wMNBSY2NwV5LHSbo9

LOYOLA UNIVERSITY CHICAGO

What is Biometrics?

8.2 billion people

Who is this person?

Is this person Jane Doe?

What is Biometrics?

8.2 billion people

Who is this person? *(Identification)*

Is this person Jane Doe? *(Verification)*

What is Biometrics?

8.2 billion people

Who is this person? *(Identification)*

Is this person Jane Doe? *(Verification)*

Biometrics aims at *identifying* or *verifying* the claimed identity of an individual based on their *physical*, *chemical,* or *behavioral* traits.

What is Biometrics?

In this course, we aim at **computer-aided Biometrics**.

We'll focus on **software solutions** rather than hardware.

But we'll get to use some **devices**, I promise.

What is Biometrics?

Identity verification through:

✓ A unique trait of yours.

physical

chemical

behavioral

✗ Not something you **have**.

✗ Not something you **know**.

LOYOLA UNIVERSITY CHICAGO

Why use Biometrics?

Consumers prefer biometric authentication to traditional passwords, Visa says

Jan 6, 2020 | Chris Burt

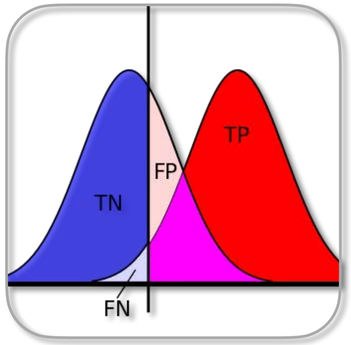
CATEGORIES Biometrics News | Financial Services

Almost 70 percent of U.S. shoppers did not go through with an online purchase because they either forgot the password, couldn't log in or couldn't receive a one-time passcode, according to research conducted by Visa, while another report from Verizon found that as many as 80 percent of data breaches are caused by compromised and weak passwords.

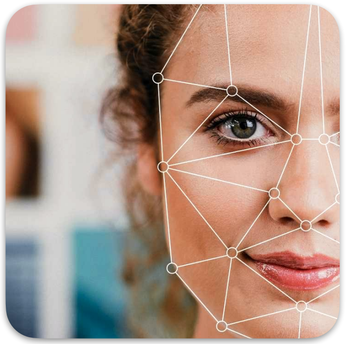
https://www.biometricupdate.com/202001/consumers-prefer-biometric-authentication-to-traditional-passwords-visa-says

Course Overview

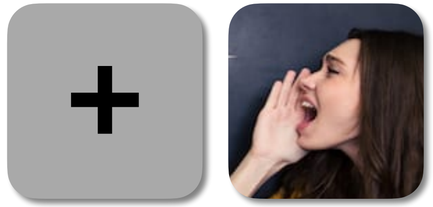
Content



Basics
Concepts
Metrics
Metric implementation



Core Traits (3)
Concepts
Baseline implementation
Data collection
Evaluation
Attacks
Assignments



Alternative Traits and Fusion
Concepts

Invited Talks (2)
State of the art
Future work

LOYOLA UNIVERSITY CHICAGO

Course Overview

Structure *(tentative)*
23 lectures
4 in-class coding days with data collection
2 invited talks

Workload
4 assignments
2 exams (midterm and final)
1 project with written report and presentation

Course Overview

Schedule

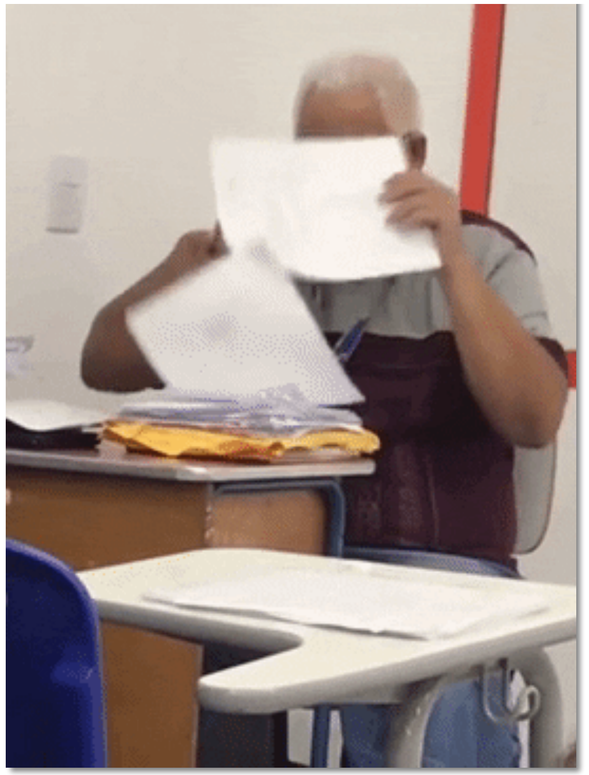
- 08/25 - Syllabus, Course details.
- 08/27 - Basics I, Biometrics, traits, and systems.
- 09/01 - Labor Day, *no classes.*
- 09/03 - Reading Activity, *no sync class.*
- 09/08 - Basics II, Biometric systems, errors, and metrics.
- 09/10 - 1st Coding Class, Metrics' implementation.
- 09/15 - Fingerprint Recog. I, History and features.
- 09/17 - Fingerprint Recog. II, Acquisition and enhancement.
- 09/22 - Fingerprint Recog. III, Minutiae detection.
- 09/24 - Fingerprint Recog. IV, Data collection.
- 09/29 - 2nd Coding Class, Fingerprint recognition.
- 10/01 - Midterm Preparation, Recap, and project discussion.
- 10/06 - Fall Break, *no classes.*
- 10/08 - Midterm Exam, *good luck.*
- 10/13 - Face Recog. I, Why faces and faces vs. other traits.
- 10/15 - Face Recog. II, Acquisition and enhancement.
- 10/20 - Face Recog. III, Description and matching.
- 10/22 - Face Recog. IV, Deep learning face recognition.
- 10/27 - 3rd Coding Class, Face recognition.
- 10/29 - Iris Recog. I, Why irises and irises vs. other traits.
- 11/03 - Iris Recog. II, Acquisition and enhancement.
- 11/05 - Iris Recog. III, Description and matching.
- 11/10 - 4th Coding Class, Iris recognition.
- 11/12 - Other Traits, Alternative traits and Soft Biometrics.
- 11/17 - Multibiometrics, Data fusion.
- 11/19 - Feature Indexing, Index building and feature querying.
- 11/24 - 1st Invited Talk, *more info soon.*
- 11/26 - Thanksgiving, *no classes.*
- 12/01 - 2nd Invited Talk, *more info soon.*
- 12/03 - Project presentations, *show time.*
- 12/08 - Final Exam, *good luck.*

Course Overview

Grading

	Undergraduate	Graduate
Assignments (4)	40%	25%
Exams (2)	50%	40%
Project	10% (extra)	25%
Participation	10%	10%
On the News	1% (extra)	1% (extra)

A [96, 100)	B+ [88, 92)	C+ [76, 80)	D+ [64, 68)
A- [92, 96)	B [84, 88)	C [72, 76)	D [60, 64)
	B- [80, 84)	C- [68, 72)	F (0, 60)

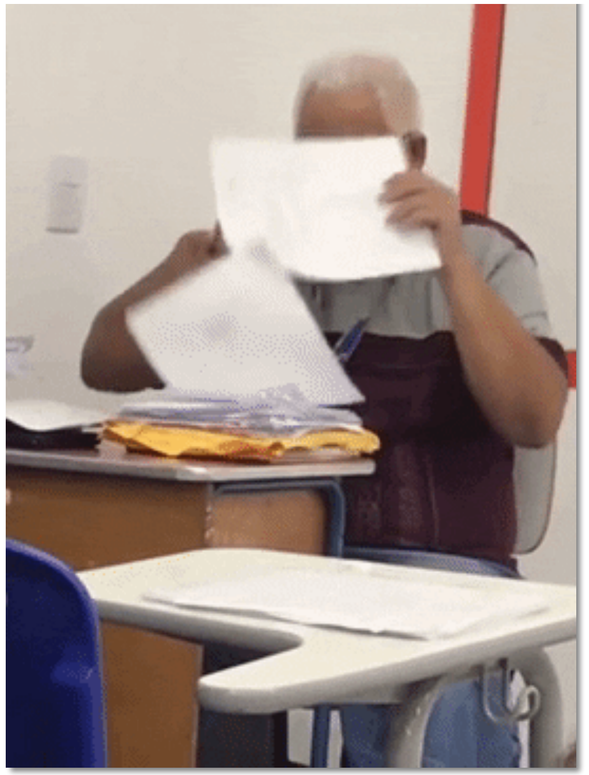


Course Overview

Grading

	Undergraduate	Graduate
Assignments (4)	40%	25%
Exams (2)	50%	40%
Project	10% (extra)	25%
Participation	10%	10%
On the News	1% (extra)	1% (extra)

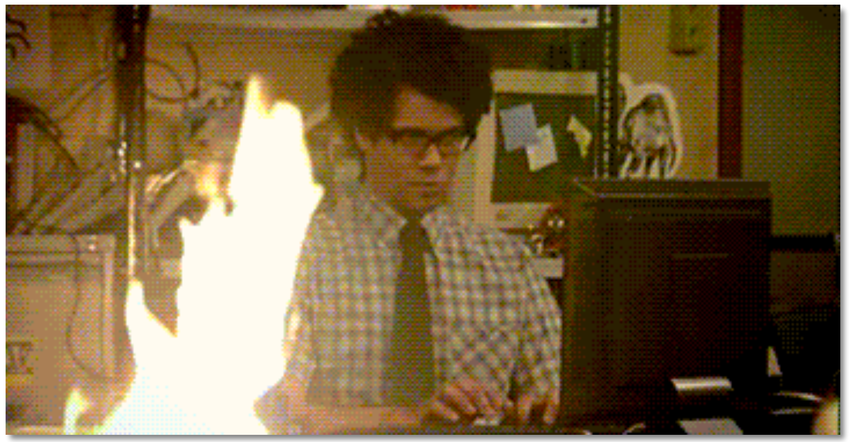
A [96, 100)	B+ [88, 92)	C+ [76, 80)	D+ [64, 68)
A- [92, 96)	B [84, 88)	C [72, 76)	D [60, 64)
	B- [80, 84)	C- [68, 72)	F (0, 60)



Course Overview

Assignments
Individual take-home activities
Submission through Sakai

Late policy: -10% of the maximum possible grade for each day of delay.



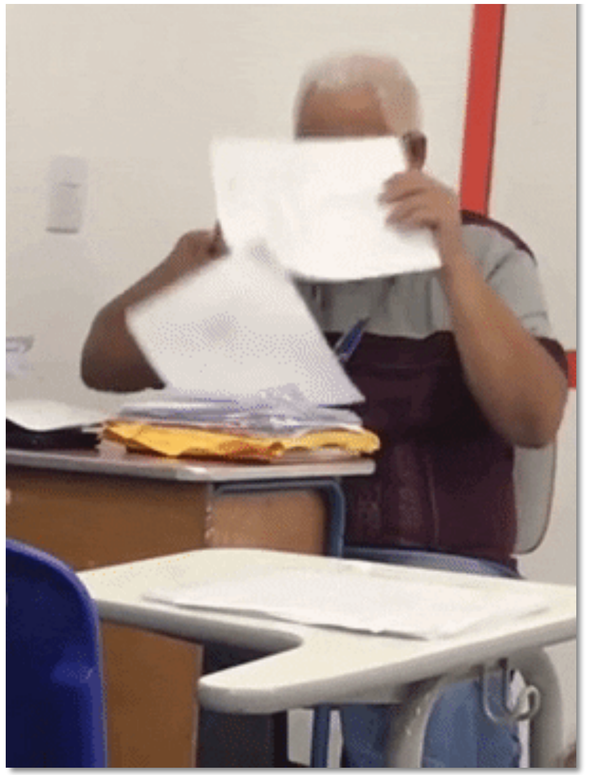
Assignment 1	Assignment 2	Assignment 3	Assignment 4
Metric Collection	Fingerprint Recognition	Face Recognition	Iris Recognition

Course Overview

Grading

	Undergraduate	Graduate
Assignments (4)	40%	25%
Exams (2)	50%	40%
Project	10% (extra)	25%
Participation	10%	10%
On the News	1% (extra)	1% (extra)

A [96, 100)	B+ [88, 92)	C+ [76, 80)	D+ [64, 68)
A- [92, 96)	B [84, 88)	C [72, 76)	D [60, 64)
	B- [80, 84)	C- [68, 72)	F (0, 60)

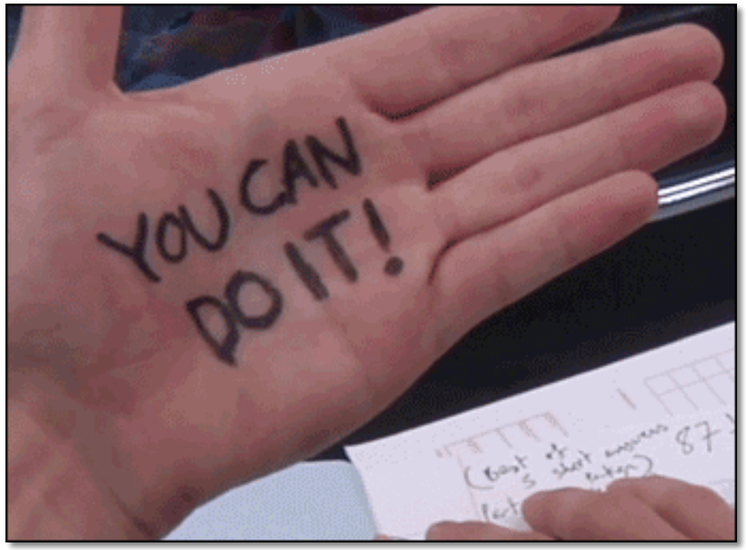


Course Overview

Exams

10/08: in-class written midterm
12/08: in-class written final

One-page cheat sheet is allowed.

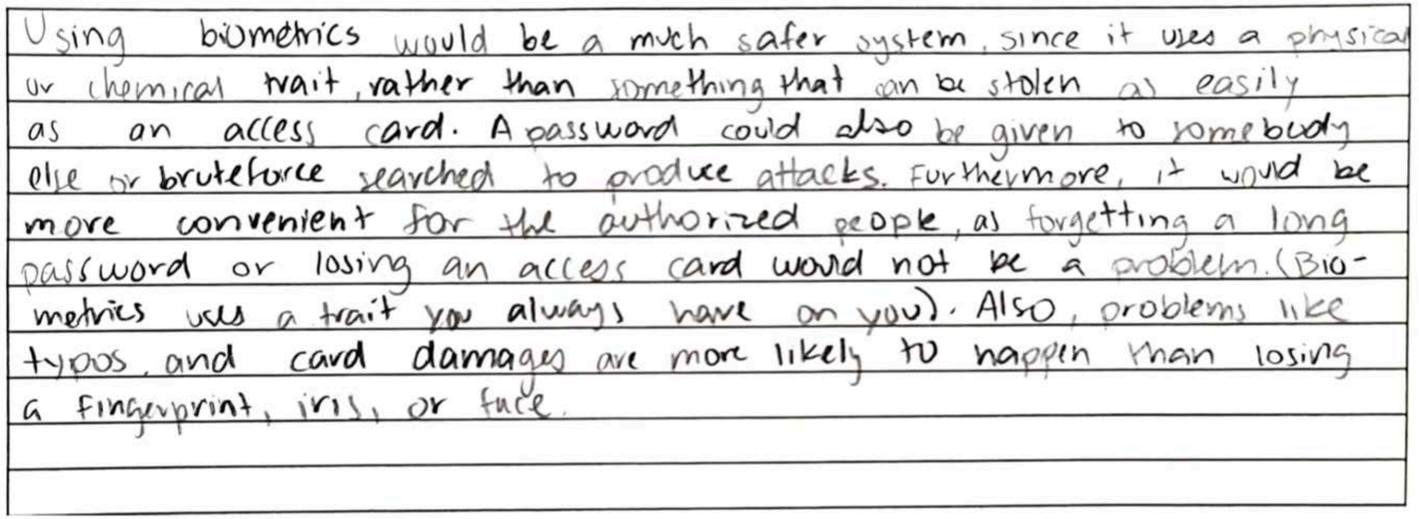


Course Overview

Exams

Style example.

[Question 1] (2 points)
Suppose you were hired by a bank company to coordinate the deployment of an access management system to control the entrance of authorized people into the many vaults spread among different branches. The bank directors have heard about Biometrics but are not certain about the benefits of using it. They think using simple access cards and long passwords is as effective and much cheaper than using a biometric system. If it is your duty to change their mind, **what would you say to convince them**?

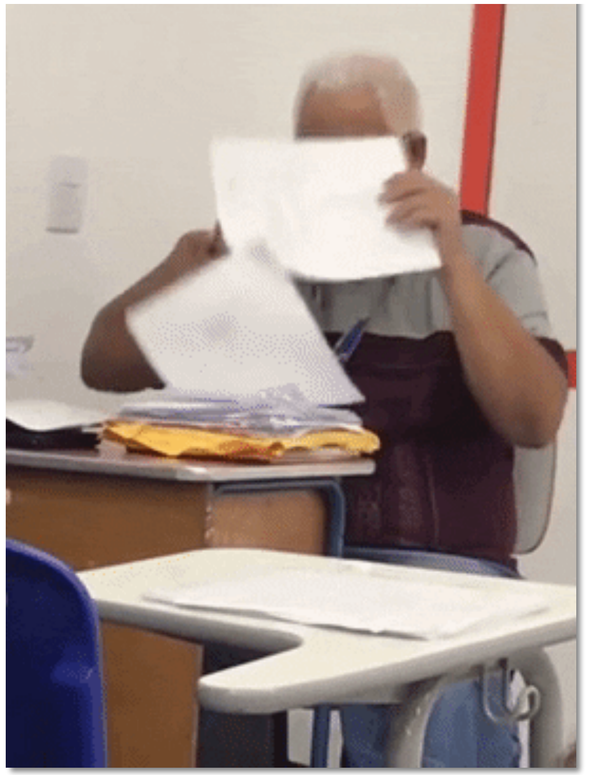

Using biometrics would be a much safer system, since it uses a physical or chemical trait, rather than something that can be stolen as easily as an access card. A password could also be given to somebody else or bruteforce searched to produce attacks. Furthermore, it would be more convenient for the authorized people, as forgetting a long password or losing an access card would not be a problem. (Biometrics uses a trait you always have on you). Also, problems like typos, and card damages are more likely to happen than losing a fingerprint, iris, or face.

Course Overview

Grading

	Undergraduate	Graduate
Assignments (4)	40%	25%
Exams (2)	50%	40%
Project	10% (extra)	25%
Participation	10%	10%
On the News	1% (extra)	1% (extra)

A [96, 100)	B+ [88, 92)	C+ [76, 80)	D+ [64, 68)
A- [92, 96)	B [84, 88)	C [72, 76)	D [60, 64)
	B- [80, 84)	C- [68, 72)	F (0, 60)



Course Overview

Project
Work alone or in groups.
Provide a written report and perform a presentation.

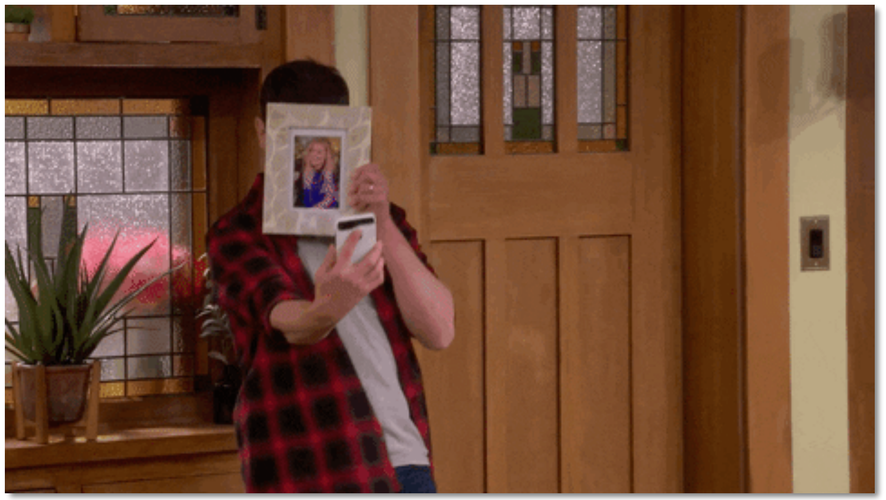
Optional for undergraduate students (it will grant extra points).

Course Overview

Project

Possible Topics
Presentation attack
(performance, detection, and mitigation)
of fingerprint, face, or iris recognition.

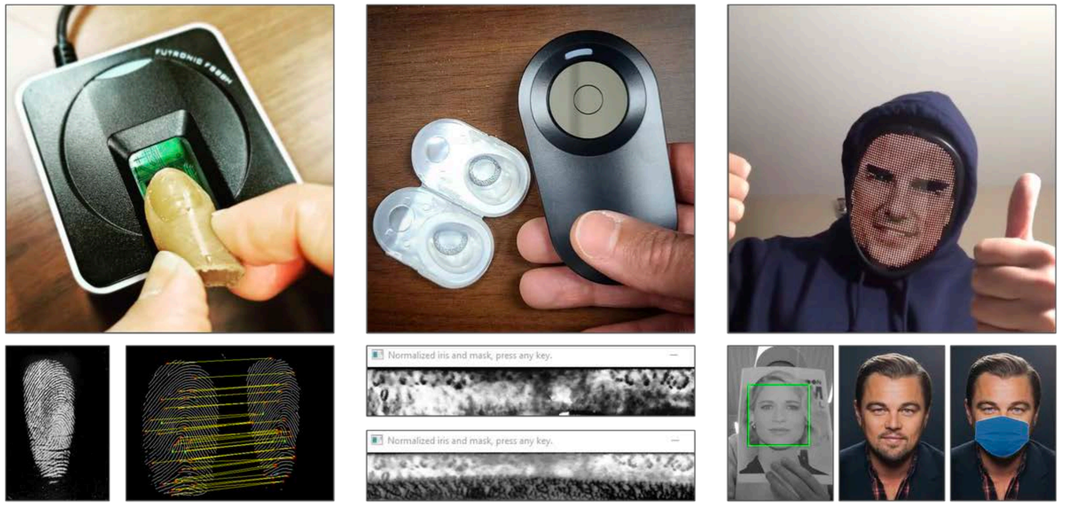
Implementation of recognition of traits
other than fingerprints, face, and iris.



Course Overview

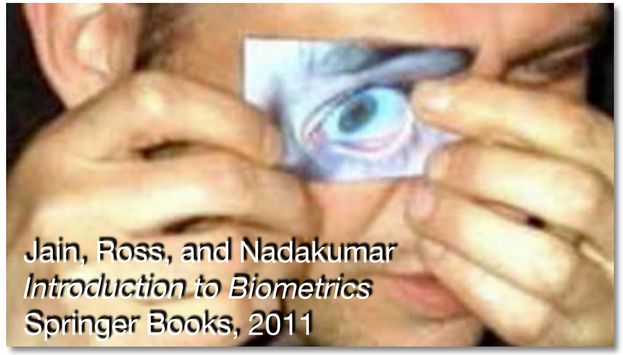
Project

Possible Topics *(continued)*
Implementation of a complete class attendance system.



Presentation and
implementation of state-of-the-art scientific publications.

Discussion about the ethical aspects of Biometrics and surveillance.



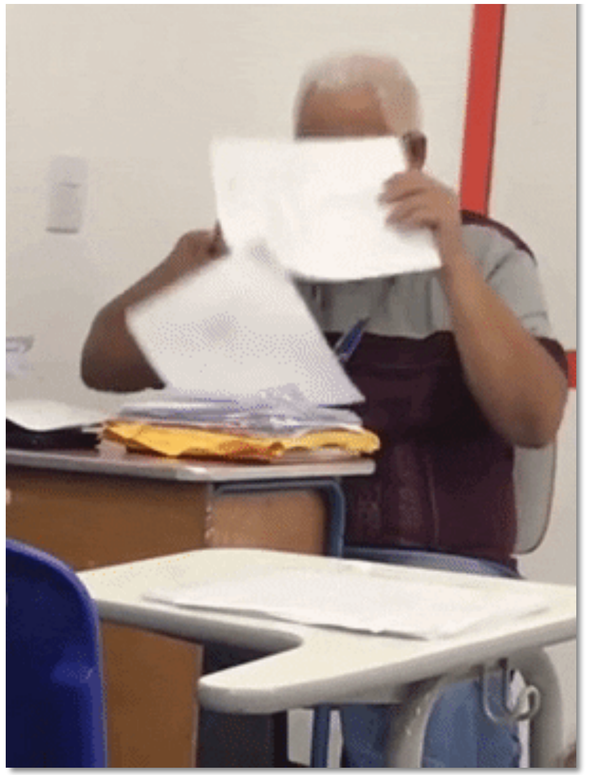
LOYOLA UNIVERSITY CHICAGO

Course Overview

Grading

	Undergraduate	Graduate
Assignments (4)	40%	25%
Exams (2)	50%	40%
Project	10% (extra)	25%
Participation	10%	10%
On the News	1% (extra)	1% (extra)

A [96, 100)	B+ [88, 92)	C+ [76, 80)	D+ [64, 68)
A- [92, 96)	B [84, 88)	C [72, 76)	D [60, 64)
	B- [80, 84)	C- [68, 72)	F (0, 60)



Course Overview

Participation

Class Attendance
Every presence counts.
It is possible to get extra points based on interest and proactivity.

Course Overview

Participation

***Today-I-missed* Statements**
Submit **on Sakai** after every class.
Answer one of

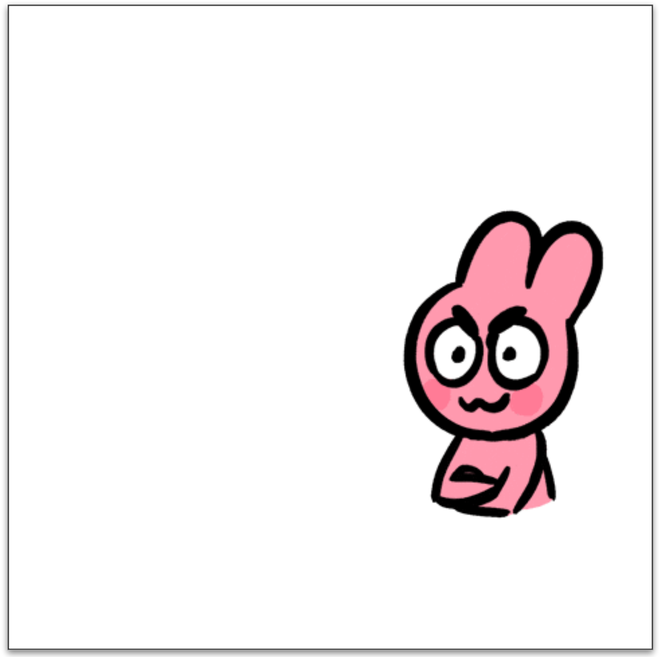
What is your biggest question after class?
or
What was the most interesting point you learned today?

Course Overview

Participation

Grace Cards
Life happens, each student has 3 cards.

Cards can be used to excuse absences
or late-delivered work (up to 9 days of delay).

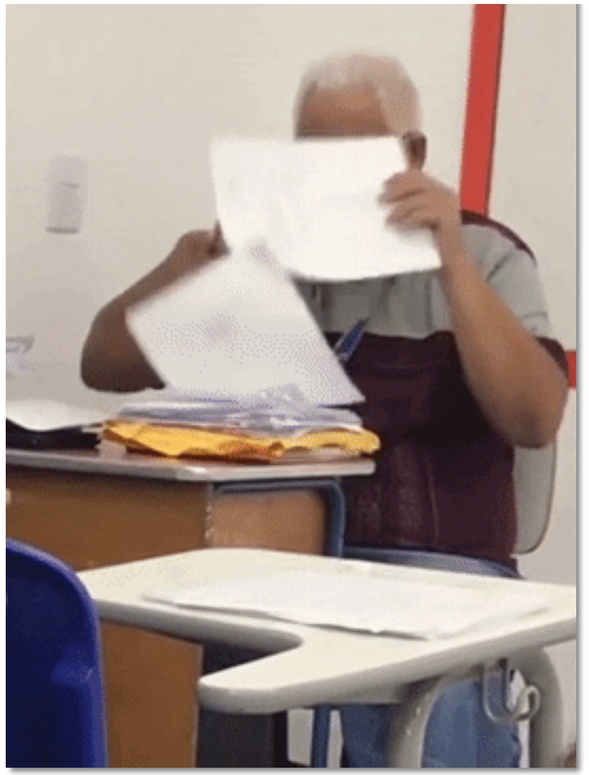


Course Overview

Grading

	Undergraduate	Graduate
Assignments (4)	40%	25%
Exams (2)	50%	40%
Project	10% (extra)	25%
Participation	10%	10%
On the News	1% (extra)	1% (extra)

A [96, 100)	B+ [88, 92)	C+ [76, 80)	D+ [64, 68)
A- [92, 96)	B [84, 88)	C [72, 76)	D [60, 64)
	B- [80, 84)	C- [68, 72)	F (0, 60)



Course Overview

Biometrics on the News

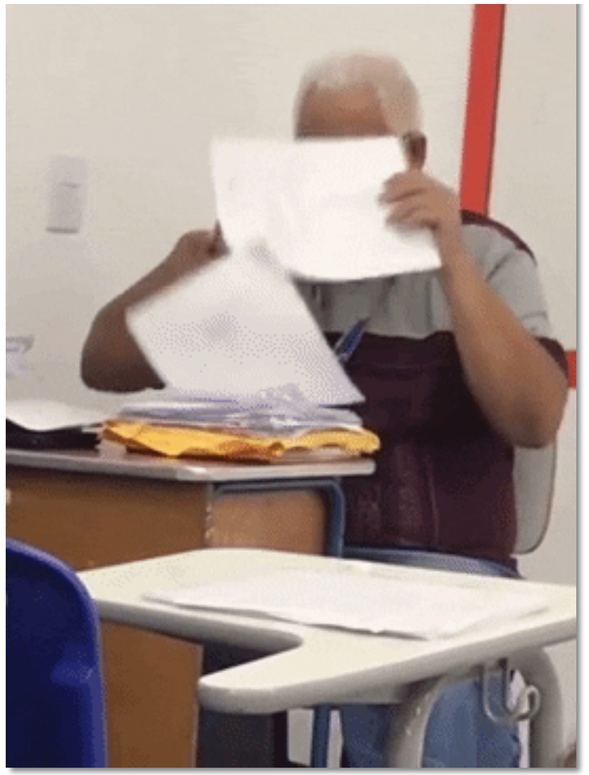
Share with us news you find related to Biometrics.

Get extra points for doing that.

Course Overview

Grading

	Undergraduate	Graduate
Assignments (4)	40%	25%
Exams (2)	50%	40%
Project	10% (extra)	25%
Participation	10%	10%
On the News	1% (extra)	1% (extra)

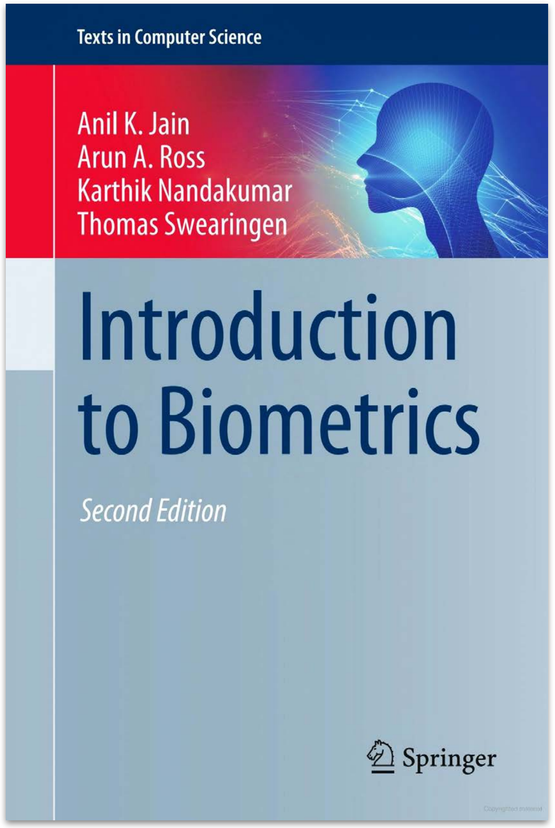


Code of Honor
Please refer to https://tinyurl.com/25nvdbr8.
Break it and get an F.

Course Overview

Bibliography

Jain, Ross, Nandakumar, and Swearingen
Introduction to Biometrics, 2nd Edition
Springer Books, 2025



LOYOLA UNIVERSITY CHICAGO

Course Overview

Pre-requisites

Essential
Programming, basic prob & stats,
and data structures

Desired
Python, Numpy, Matplotlib, and OpenCV

Not sure?
Please talk to me in private.

Course Overview

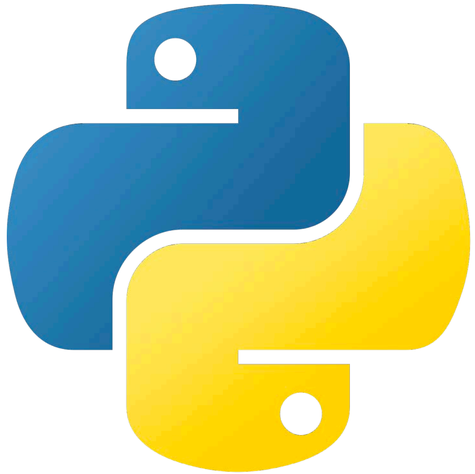
Data Collection

We'll collect only **our own biometric** data (instructor's and students').
Our data **will only be used** for the purpose of the course.
Our data **will not be shared** with anybody outside the course.
Our data **will be deleted** after the course.

During assignments, folks in need of other publicly available biometric databases are welcome to contact me, so we can take care of privacy and copyright issues.

Course Overview

Why Python?
High-level enough
General-purpose enough
Good code readability

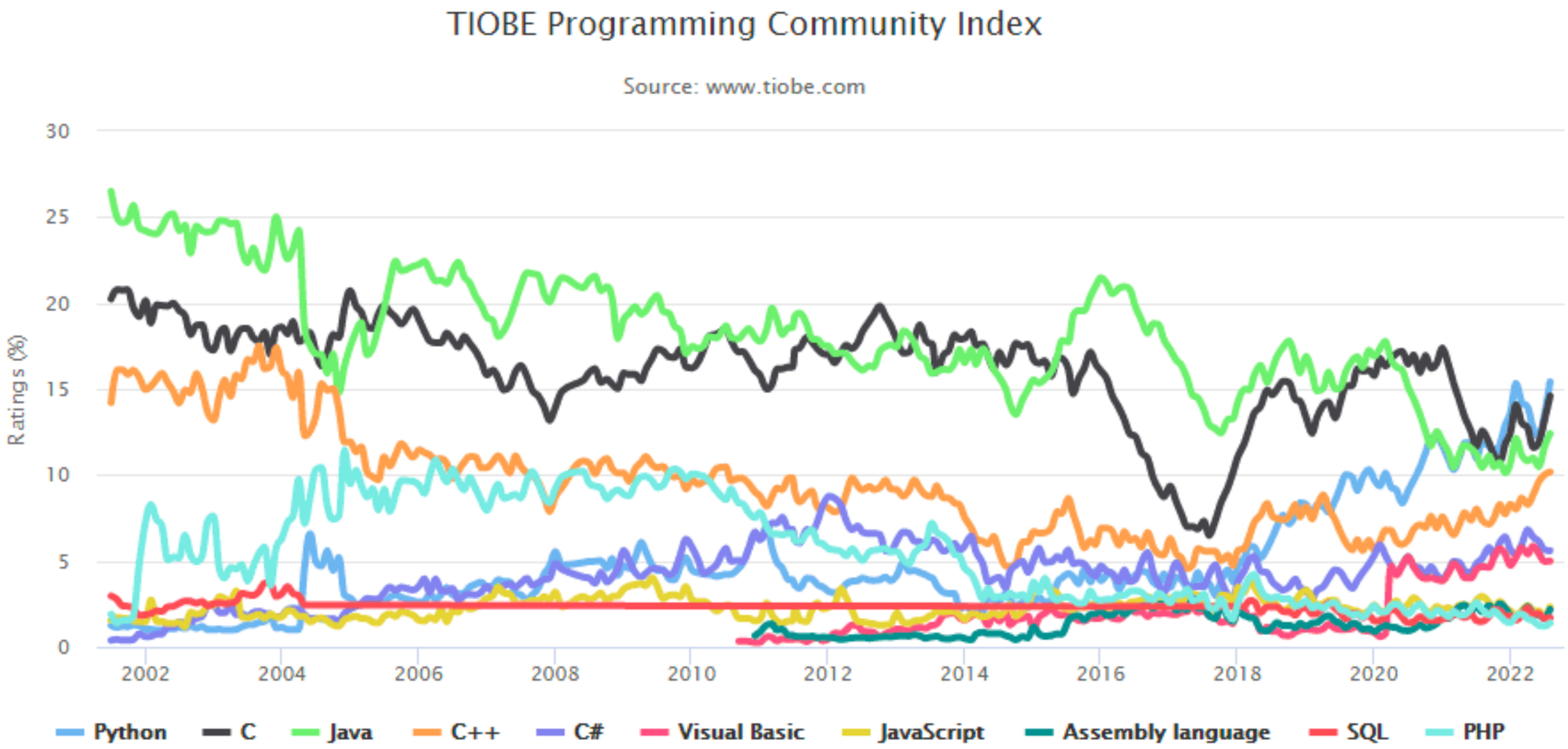


High productivity in data processing
(easy to manipulate strings, lists, and dictionaries).

Large supporting community.
Good libraries supporting scientific computing
(e.g., Numpy, ScyPy, Matplotlib).

Course Overview

Why Python?
Increasing popularity



LOYOLA UNIVERSITY CHICAGO

Course Overview

Jupyter Notebooks
Interactive computing

Adoption of the *notebook* interface:
Multiple cells for (1) explanation,
(2) coding, and (3) output of results.

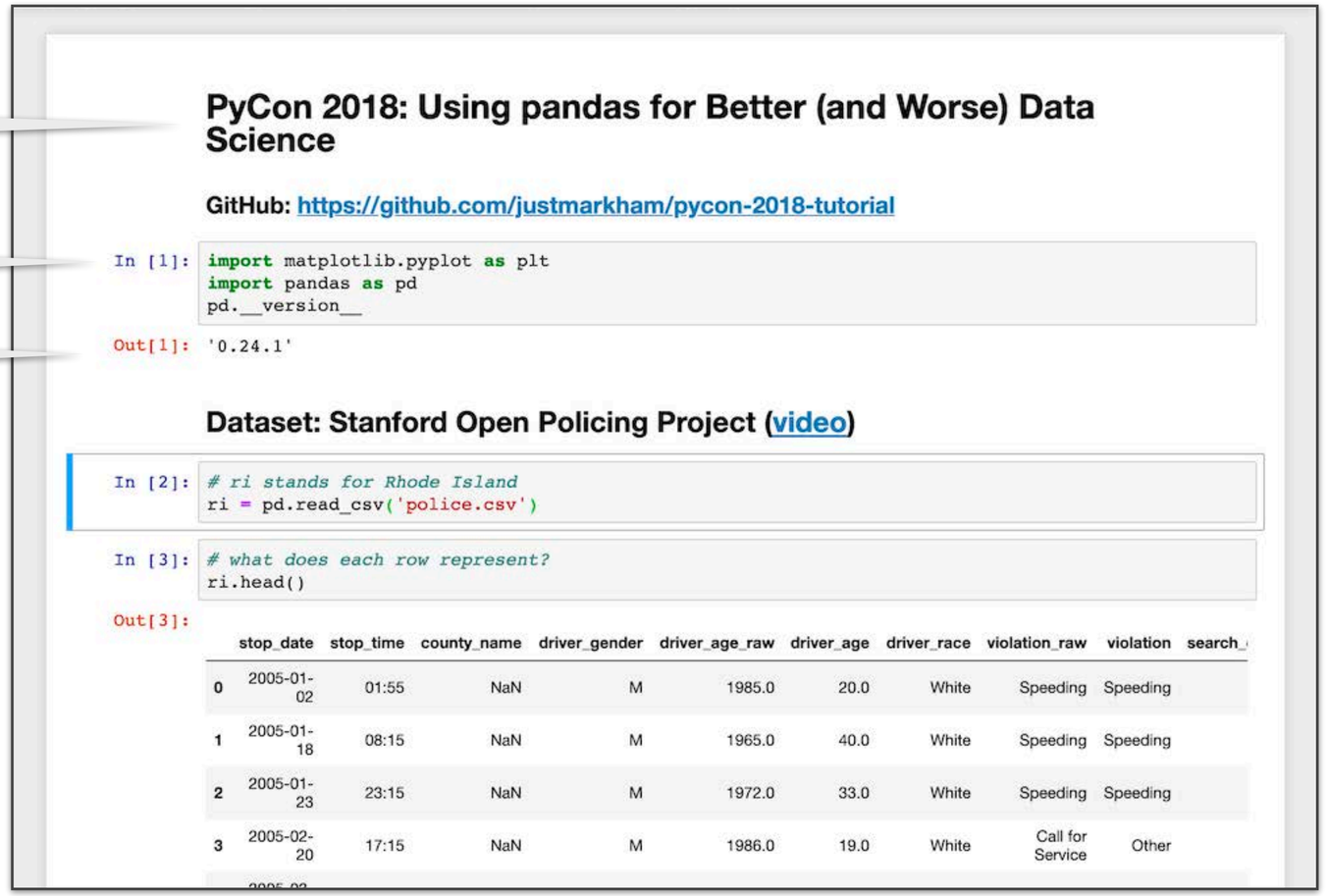
Course Overview

Jupyter Notebooks

explanation

coding

output



PyCon 2018: Using pandas for Better (and Worse) Data Science

GitHub: https://github.com/justmarkham/pycon-2018-tutorial

```
In [1]: import matplotlib.pyplot as plt
        import pandas as pd
        pd.__version__
```

```
Out[1]: '0.24.1'
```

Dataset: Stanford Open Policing Project (video)

```
In [2]: # ri stands for Rhode Island
        ri = pd.read_csv('police.csv')
```

```
In [3]: # what does each row represent?
        ri.head()
```

Out[3]:

	stop_date	stop_time	county_name	driver_gender	driver_age_raw	driver_age	driver_race	violation_raw	violation	search_
0	2005-01-02	01:55	NaN	M	1985.0	20.0	White	Speeding	Speeding	
1	2005-01-18	08:15	NaN	M	1965.0	40.0	White	Speeding	Speeding	
2	2005-01-23	23:15	NaN	M	1972.0	33.0	White	Speeding	Speeding	
3	2005-02-20	17:15	NaN	M	1986.0	19.0	White	Call for Service	Other	

Course Overview

Jupyter Notebooks

explanation

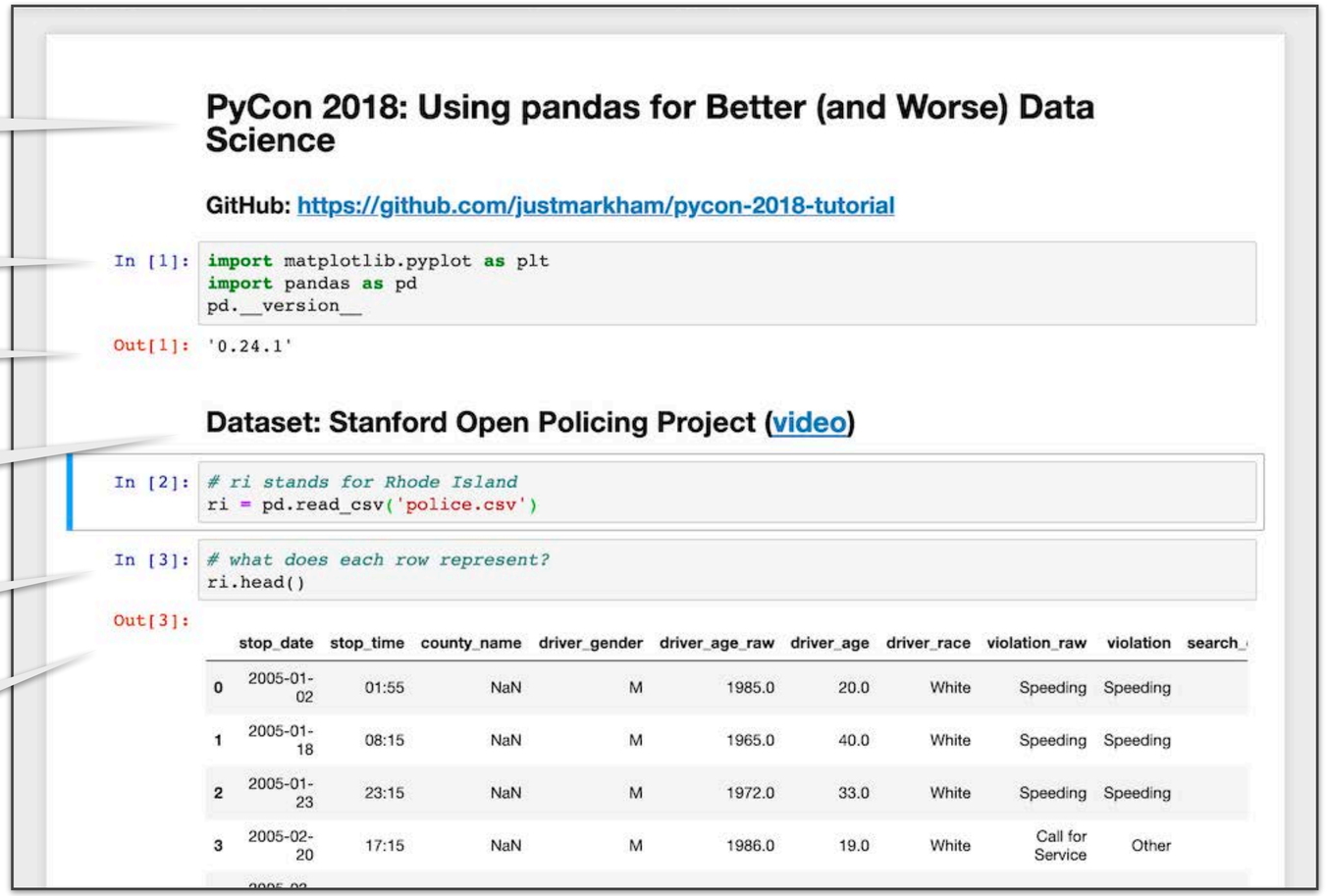
coding

output

explanation

coding

output



PyCon 2018: Using pandas for Better (and Worse) Data Science

GitHub: https://github.com/justmarkham/pycon-2018-tutorial

```
In [1]: import matplotlib.pyplot as plt
        import pandas as pd
        pd.__version__
```

```
Out[1]: '0.24.1'
```

Dataset: Stanford Open Policing Project (video)

```
In [2]: # ri stands for Rhode Island
        ri = pd.read_csv('police.csv')
```

```
In [3]: # what does each row represent?
        ri.head()
```

Out[3]:

	stop_date	stop_time	county_name	driver_gender	driver_age_raw	driver_age	driver_race	violation_raw	violation	search_
0	2005-01-02	01:55	NaN	M	1985.0	20.0	White	Speeding	Speeding	
1	2005-01-18	08:15	NaN	M	1965.0	40.0	White	Speeding	Speeding	
2	2005-01-23	23:15	NaN	M	1972.0	33.0	White	Speeding	Speeding	
3	2005-02-20	17:15	NaN	M	1986.0	19.0	White	Call for Service	Other	

Course Overview

Google Colab
https://colab.research.google.com/

You'll need a Google account.

Select "New Notebook" on the bottom right of the form.

Do your first "Hello World!"

Course Overview

Local Installation?
Please come to office hours (tinyurl.com/yv76kjpb).

Local installation of Python and Jupyter.

Any operating system.
Use your CPU.

Your Next Tasks

Relax
Any issues? Please come and talk to me.

Sakai is up!
Please visit it as soon as possible.
Important announcements will be made there.

Start filling out your *Today-I-missed* Statement
Please visit sakai.luc.edu/x/BCJs8K.