

Early Fire Detection System using YOLOv8

Group 24

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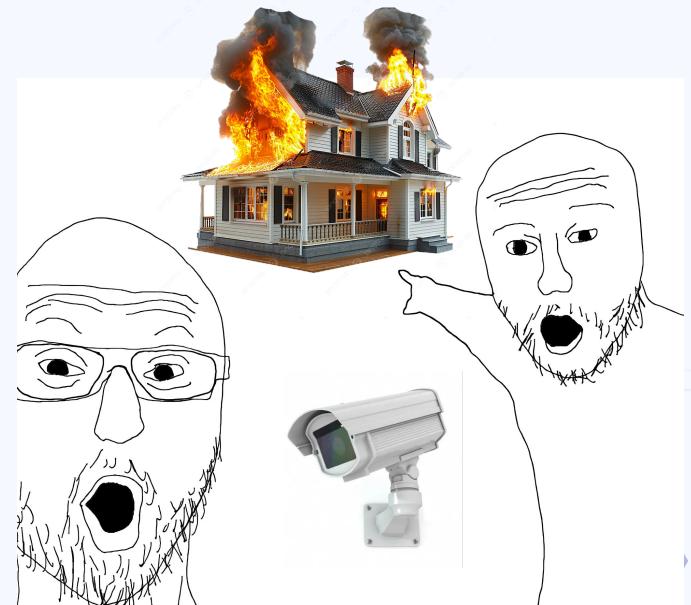


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Quantitative Results
Demo

01

Problem Statement

- Context
- Traditional approaches
- Deep Learning Approach with YOLO

Context: Fire Incidents in Vietnam

Statistics

Over 2,000 fire accidents
in houses and warehouses
(2024) [1]

Over 6 billions of VND in
damage [1]

Causes

- Short circuits
- Overloaded power
- Smoking

Challenges

- Lack of early detection
- Slow emergency response
- Limited awareness

Traditional Approaches

Conventional Alarm System

- Smoke Detectors
- Heat Sensors
- Manual Alarms

⇒ Limitations:

- Delayed response
- False alarms
- No remote monitoring



Camera Surveillance

- Record footage without analysis
- Require human supervision
- Not scalable for continuous and large scale



ML / DL Approach: YOLO

- **YOLO** (You Only Look Once) is a powerful object detection algorithm in terms of **speed**.

- **Light weight** models can be deployed on edge devices.

- **Versatility:**

- Trainable on custom dataset

- Works well on any background settings

Real-Time Detectors	Train	mAP	FPS
100Hz DPM [30]	2007	16.0	100
30Hz DPM [30]	2007	26.1	30
Fast YOLO	2007+2012	52.7	155
YOLO	2007+2012	63.4	45

Less Than Real-Time

Fastest DPM [37]	2007	30.4	15
R-CNN Minus R [20]	2007	53.5	6
Fast R-CNN [14]	2007+2012	70.0	0.5
Faster R-CNN VGG-16[27]	2007+2012	73.2	7
Faster R-CNN ZF [27]	2007+2012	62.1	18
YOLO VGG-16	2007+2012	66.4	21

02

Project Overview

- Key Objectives
- Model Pipelines



Key Objectives

Main Goal:

Build a real-time fire detection system using YOLOv8 that can accurately detect fire in live video streams and alert users immediately

Performance Metrics

- mAP@0.5 > 90%
- Precision > 85%
- Recall > 85%

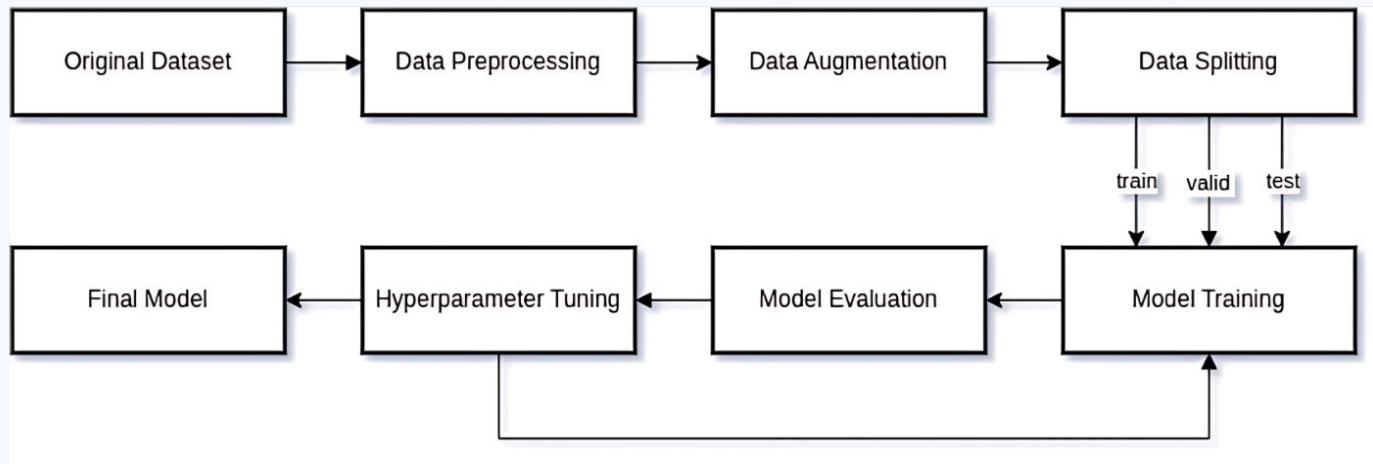
Speed

Process over 30FPS
on edge devices

Alarm

Alert users of fire
risques via Telegram
notification

Model Pipeline: Training



Model Pipeline: Inference



1. Resize image(frame)
2. Run model
3. Non-max suppression



Alert via
Telegram

YES

Has
fire?

03

Dataset

-
- Data sources
 - Annotations and Preprocessing
 - Exploratory Data Analysis

Data Sources

Public dataset on Roboflow: [fire and smoke](#)

3884 images

- Training: 2713
- Validation: 728
- Testing: 443

Image size: Varies

2 Classes: 'fire', 'smoke'

Augmentation: Not applied



Sample annotated image

Annotations & Preprocessing

Annotations

- Use bounding boxes to label fire and smoke in images
- Labels are in YOLO format:
<label> <x_center> <y_center> <width> <height>

Preprocessing

- Stretch image size to 640 x 640
- Apply Auto-Orient

Exploratory Data Analysis

Number of images

- Training set: 2712
- Validation set: 728
- Testing set for the model: 443

Observation

Images are auto-oriented → necessary to apply Data Augmentation



Exploratory Data Analysis

Bounding box Analysis

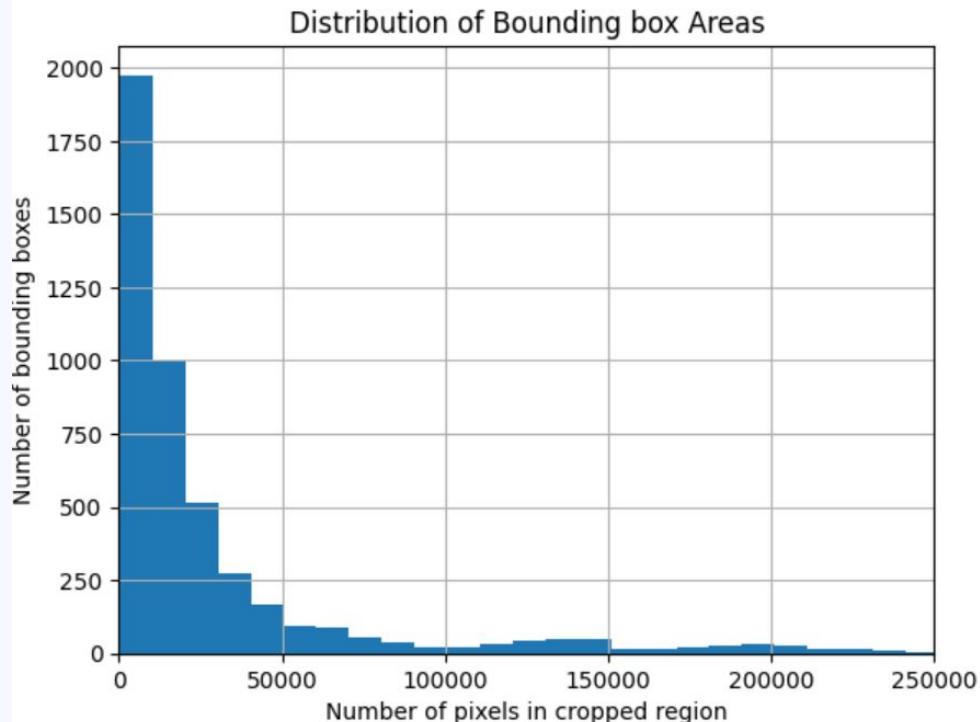
There is **no images without bounding boxes**

Observation

Size of bounding boxes varies from 1000 to 250000 pixels per image

→ **Various types of fire:**

- Big fire
- Small/Starting fire

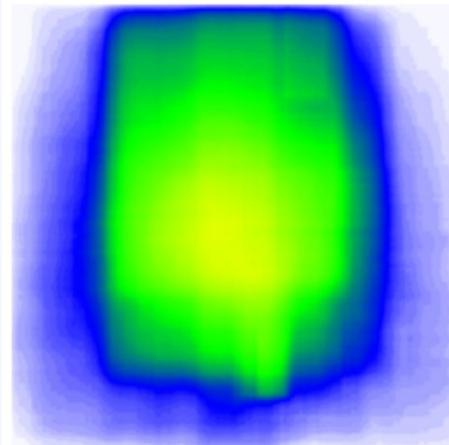


Exploratory Data Analysis

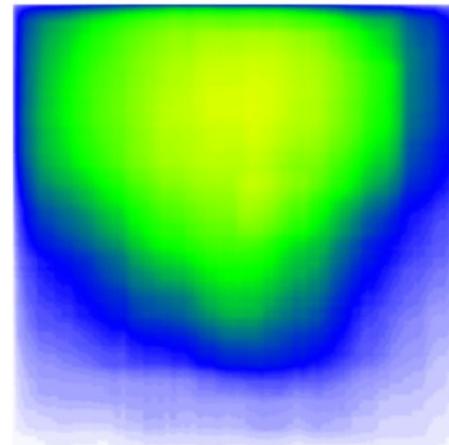
Bounding box Analysis

- Fire regions tend to concentrate in the center of the image + grows vertically
- Smoke regions occupy the upper half + more horizontally spread than fire
→ Annotations follow realistic distribution of fire and smoke.

Fire annotation heatmap



Smoke annotation heatmap



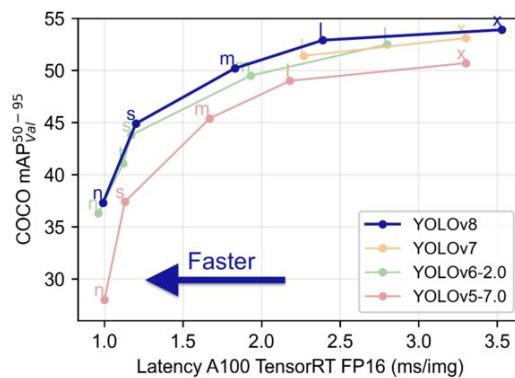
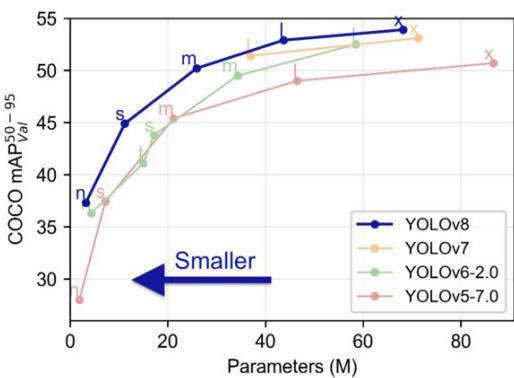
04

YOLO Model

- Architecture Breakdown
- Model Selection



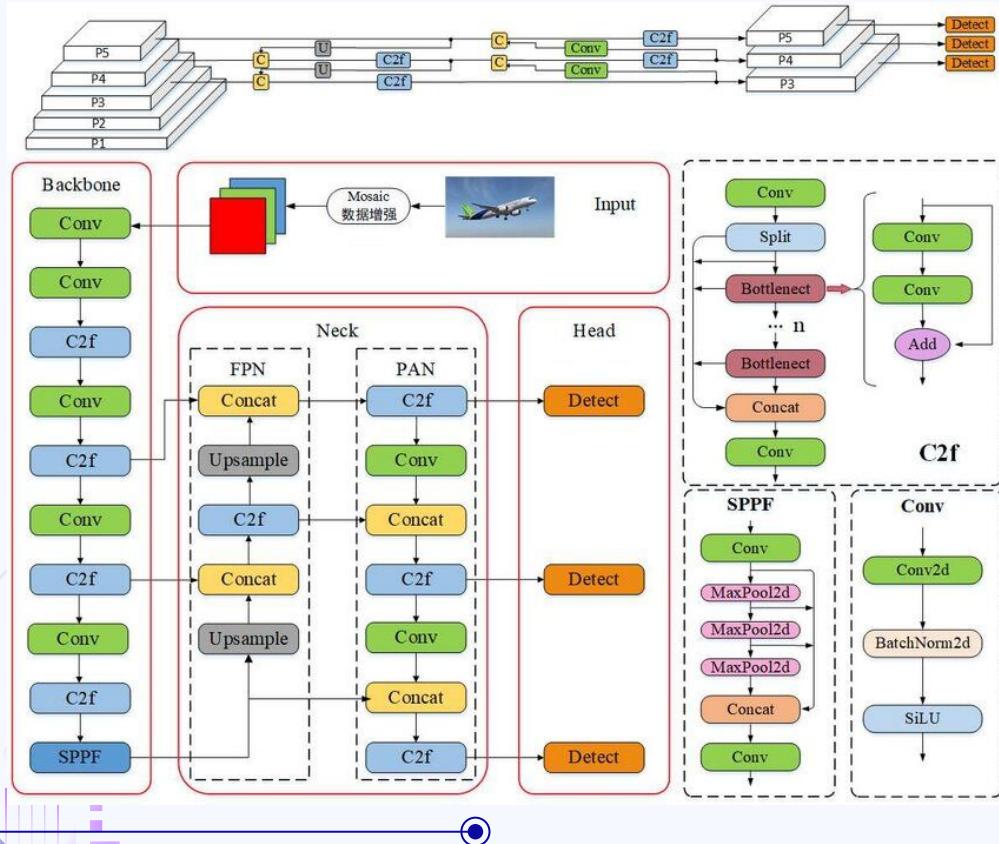
Model Variants



The diagram illustrates the network architectures of the YOLOv8 variants. The Nano variant is highlighted with a red circle.

Variant	Architecture	Size	Latency	mAP
YOLOv8n	Nano (circled)	6.5 MB	0.99 ms _{A100}	37.3 mAP _{COCO}
YOLOv8s	Small	22.6 MB	1.2 ms _{A100}	44.9 mAP _{COCO}
YOLOv8m	Medium	52.1 MB	1.83 ms _{A100}	50.2 mAP _{COCO}
YOLOv8l	Large	87.8 MB	2.39 ms _{A100}	52.9 mAP _{COCO}
YOLOv8x	XLarge	136.9 MB	3.53 ms _{A100}	53.9 mAP _{COCO}

Network Architecture

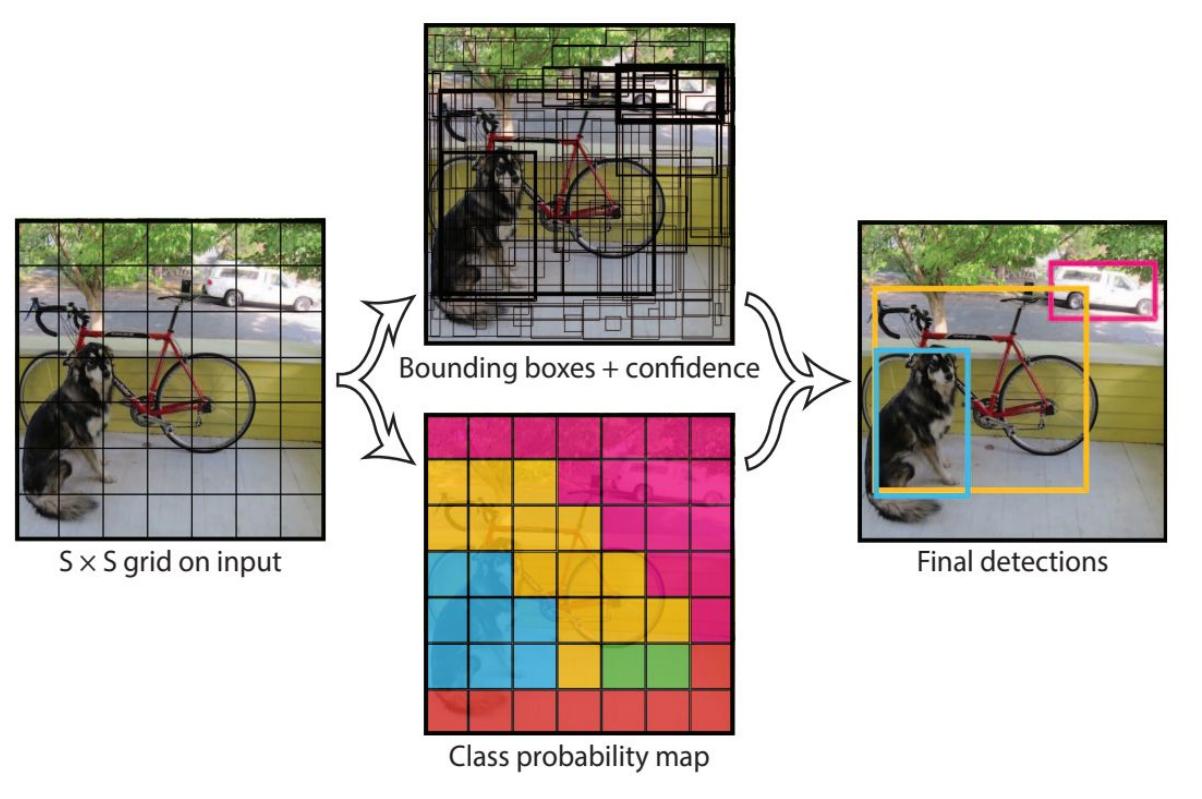


Backbone: Feature Extraction

Neck: Feature Fusion

Head: Prediction Layer

Output Structure



Loss function

Localization Loss

$$\lambda_{\text{coord}} \sum_{i=0}^{S^2} \sum_{j=0}^B \mathbb{1}_{ij}^{\text{obj}} \left[(x_i - \hat{x}_i)^2 + (y_i - \hat{y}_i)^2 \right]$$

$$+ \lambda_{\text{coord}} \sum_{i=0}^{S^2} \sum_{j=0}^B \mathbb{1}_{ij}^{\text{obj}} \left[\left(\sqrt{w_i} - \sqrt{\hat{w}_i} \right)^2 + \left(\sqrt{h_i} - \sqrt{\hat{h}_i} \right)^2 \right]$$

Object Confidence Loss

$$+ \sum_{i=0}^{S^2} \sum_{j=0}^B \mathbb{1}_{ij}^{\text{obj}} \left(C_i - \hat{C}_i \right)^2$$

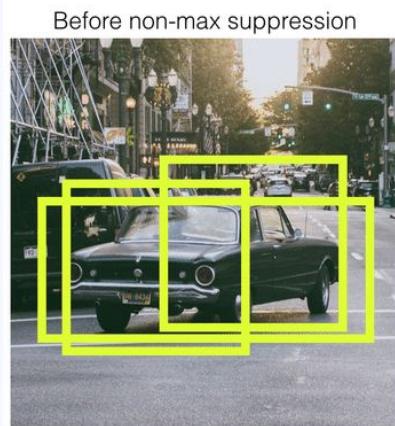
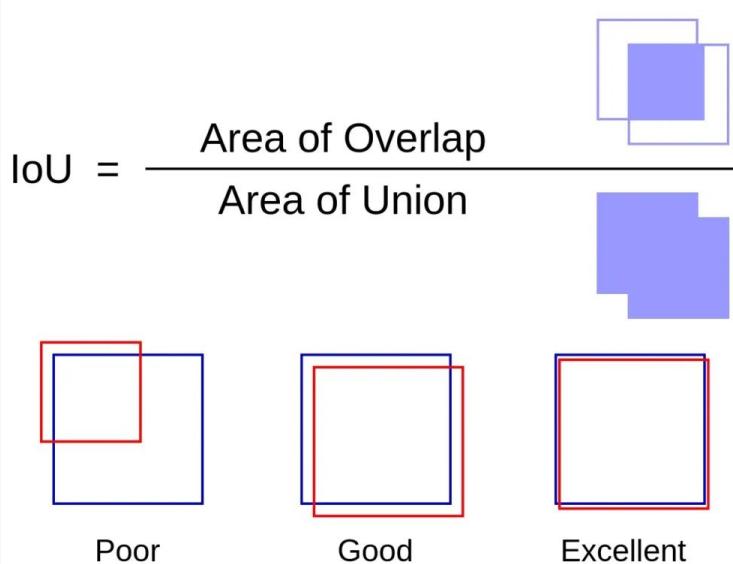
No Object Confidence Loss

$$+ \lambda_{\text{noobj}} \sum_{i=0}^{S^2} \sum_{j=0}^B \mathbb{1}_{ij}^{\text{noobj}} \left(C_i - \hat{C}_i \right)^2$$

Classification Loss

$$+ \sum_{i=0}^{S^2} \mathbb{1}_i^{\text{obj}} \sum_{c \in \text{classes}} (p_i(c) - \hat{p}_i(c))^2$$

Post processing techniques



Non-Max
Suppression

A white arrow points from the 'Before non-max suppression' image to the 'After non-max suppression' image, indicating the flow of the process.



05

Model Training

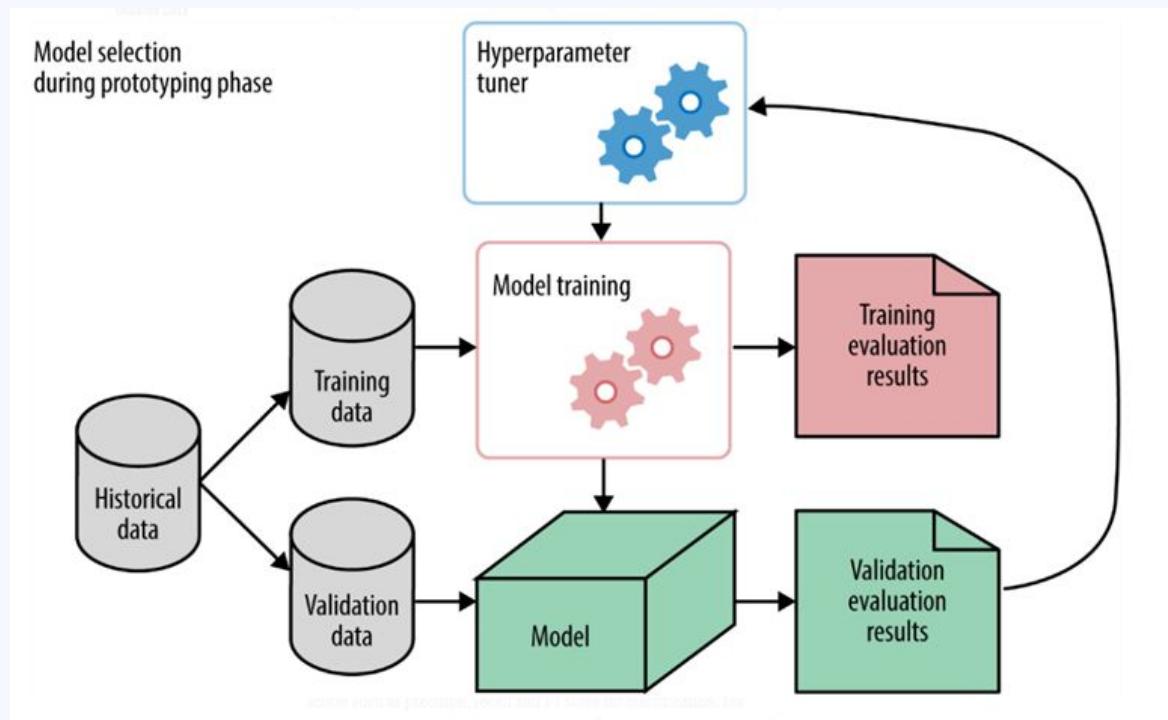
- Train the model
- Hyperparameters Tuning



Model Training

```
● ● ●  
1 # Step 1: Load the dataset from Roboflow (not augmented)  
2 from roboflow import Roboflow  
3 rf = Roboflow(api_key="BZTREFbhM5T8N26Kzvy3")  
4 project = rf.workspace("elec-g62if").project("my-first-project-ktpdl")  
5 version = project.version(2)  
6 dataset = version.download("yolov8")  
7  
8 # Step 2: Load YOLO model variant  
9 model = YOLO('yolov8n.pt')  
10  
11 # Step 3: Train  
12 model.train(  
13     data='/my-first-project-ktpdl/data.yaml',  
14     **params,  
15     verbose=False  
16 )
```

Hyperparameter tuning w/ Optuna



Hyperparameter tuning w/ Optuna

```
1 def objective(trial):
2     # Hyperparameters to search
3     params = {
4         "epochs": trial.suggest_int("epochs", 5, 100),
5         "batch": trial.suggest_categorical("batch", [8, 16, 32]),
6
7         # Augmentation
8         "flipud": trial.suggest_float("flipud", 0.0, 0.5),
9         "fliplr": trial.suggest_float("fliplr", 0.0, 0.5),
10        "mosaic": trial.suggest_float("mosaic", 0.5, 1.0),
11        "mixup": trial.suggest_float("mixup", 0.0, 0.3),
12        "degrees": trial.suggest_float("degrees", 0.0, 20.0),
13        "scale": trial.suggest_float("scale", 0.3, 0.7),
14        "shear": trial.suggest_float("shear", 0.0, 5.0),
15        "hsv_h": trial.suggest_float("hsv_h", 0.0, 0.2),
16        "hsv_s": trial.suggest_float("hsv_s", 0.0, 0.5),
17        "hsv_v": trial.suggest_float("hsv_v", 0.0, 0.5),
18        "translate": trial.suggest_float("translate", 0.0, 0.2),
19
20        # Optimizer & LR
21        "lr0": trial.suggest_float("lr0", 1e-4, 1e-2, log=True),
22        "lrf": trial.suggest_float("lrf", 0.01, 0.5),
23        ...
24    }
```

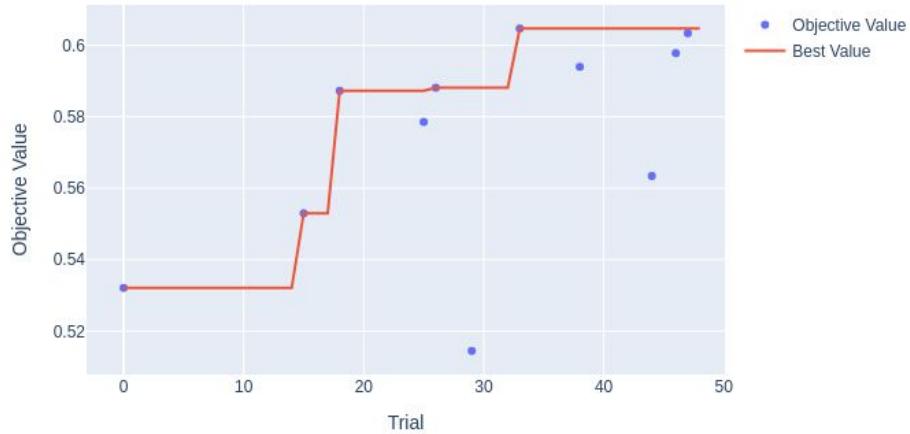
06

Results

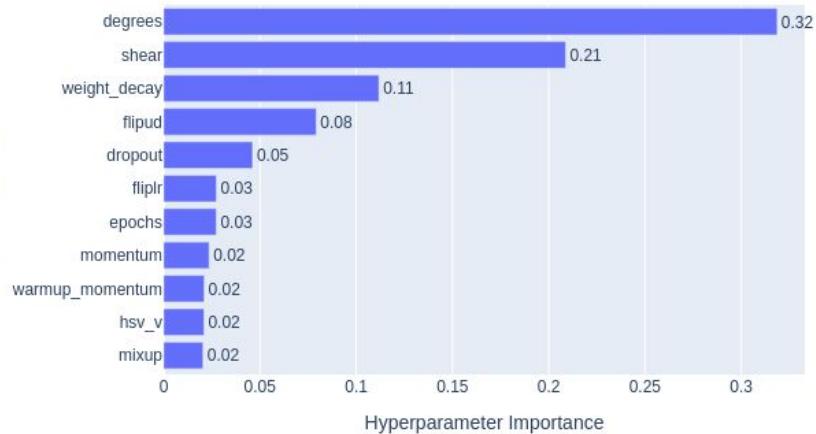
- Qualitative and Quantitative results
- Deployment and Demo

Hyperparameters Tuning Results

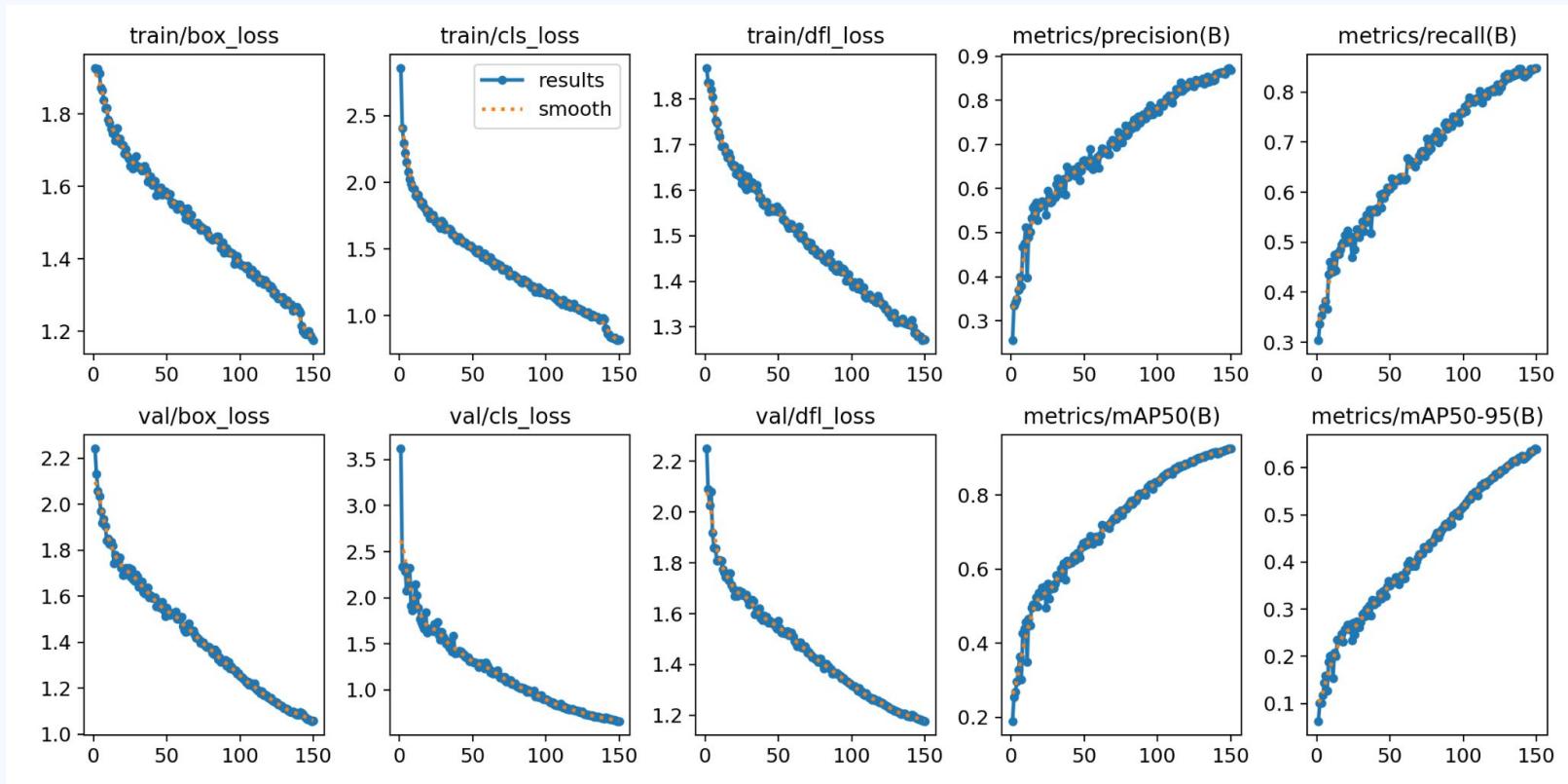
Optimization History Plot



Hyperparameter Importances



Final Model



Final Model

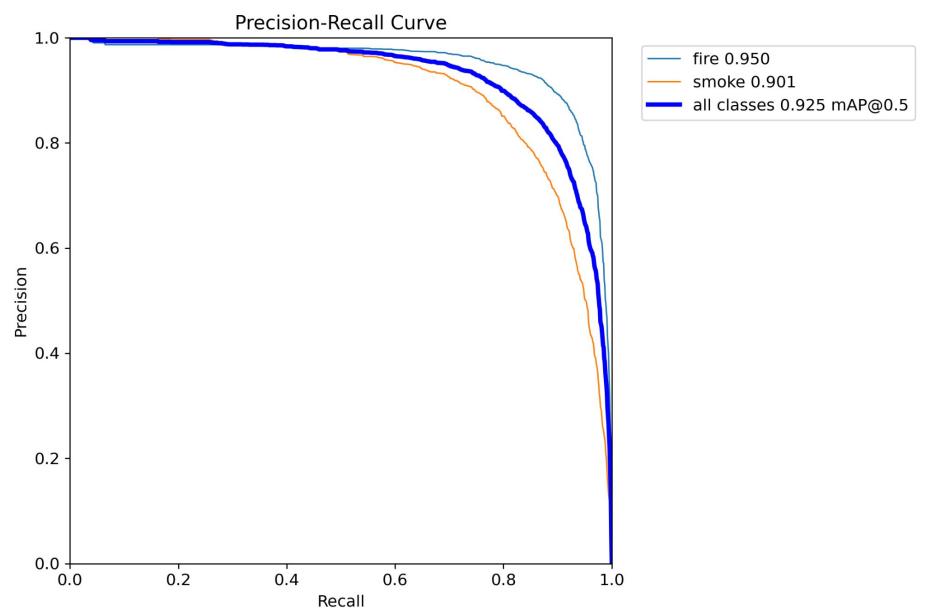
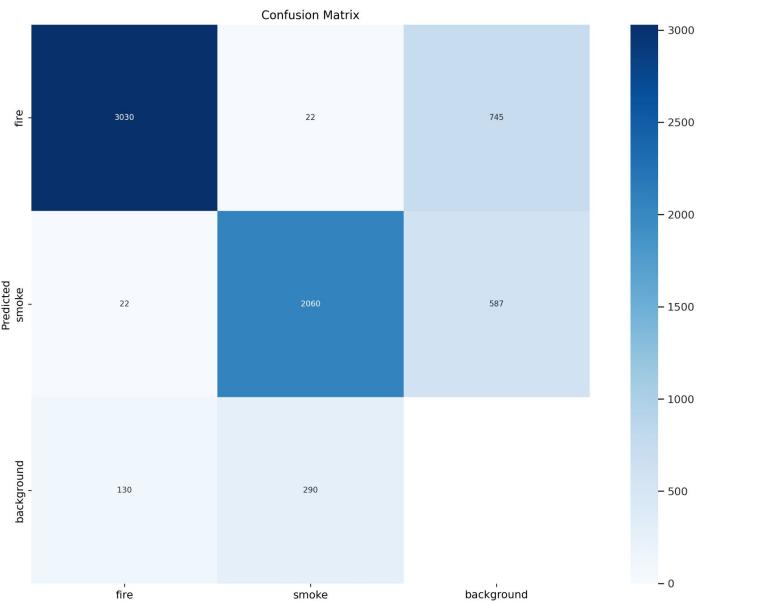


Labels



Predictions

Final Model



Demo

YouTube / New Zealand Fire Service



References

- [1] Press release on Firefighting and Rescue Operation,
Vietnamese Department of Fire and Emergency Services (2024)

Thanks !

Do you have any questions?

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Question and answer

Question

Why is fire detection important when smoke alarms already exist?

Answer

- Smoke alarms detect fire reactively
- Camera fire detection can proactively detect fires visually, even before smoke becomes dense.
- Useful in large, open places without smoke detectors

Question and answer

Question

With the dataset being mostly images, not videos, could the model falsely identify a **static object** as fire? (a painting of fire,..)

Answer

Maybe, solution: use ROI filtering (only area of movement in the frame) and feed it to the model ⇒ avoid static object, focus on moving fire.

Question and answer

Question

What are some limitations of the project?

Answer

- Requires good lighting and clear camera view.
- Sometimes confuse bright non-fire objects with real fire (false positives).
- Depends on camera coverage.

Concepts



Mercury

Mercury is the closest planet to the Sun and **the smallest one** in the Solar System—it's only a bit larger than the Moon



Venus

Venus has a beautiful name and is the **second planet from the Sun**. It's hot and has a poisonous atmosphere

What is this topic about?



Mercury

It's the closest planet to the Sun and the **smallest** in the Solar System



Venus

Venus has a beautiful name and is the second planet from the Sun



Mars

Despite being red, Mars is actually a **cold place**. It's full of iron oxide dust

Examples



Mercury

It's the closest planet to the Sun and the **smallest** in the Solar System



Venus

Venus has a beautiful name and is the second planet from the Sun



Mars

Despite being red, Mars is actually a **cold place**. It's full of iron oxide dust

Recommendations



Mars

Despite being red,
Mars is very cold



Mercury

Mercury is the closest
planet to the Sun



Venus

Venus is the second
planet from the Sun



Saturn

Saturn is a gas giant
and has several rings



Neptune

Neptune is the farthest
planet from the Sun



Jupiter

Jupiter is the biggest
planet of them all

Image always reinforce the concept

You can give a brief description of the topic you want to talk about here. For example, if you want to talk about Mercury, you can say that it's the smallest planet in the entire Solar System



4,498,300,000

Big numbers catch your audience's attention

9h 55m 23s

Jupiter's rotation period

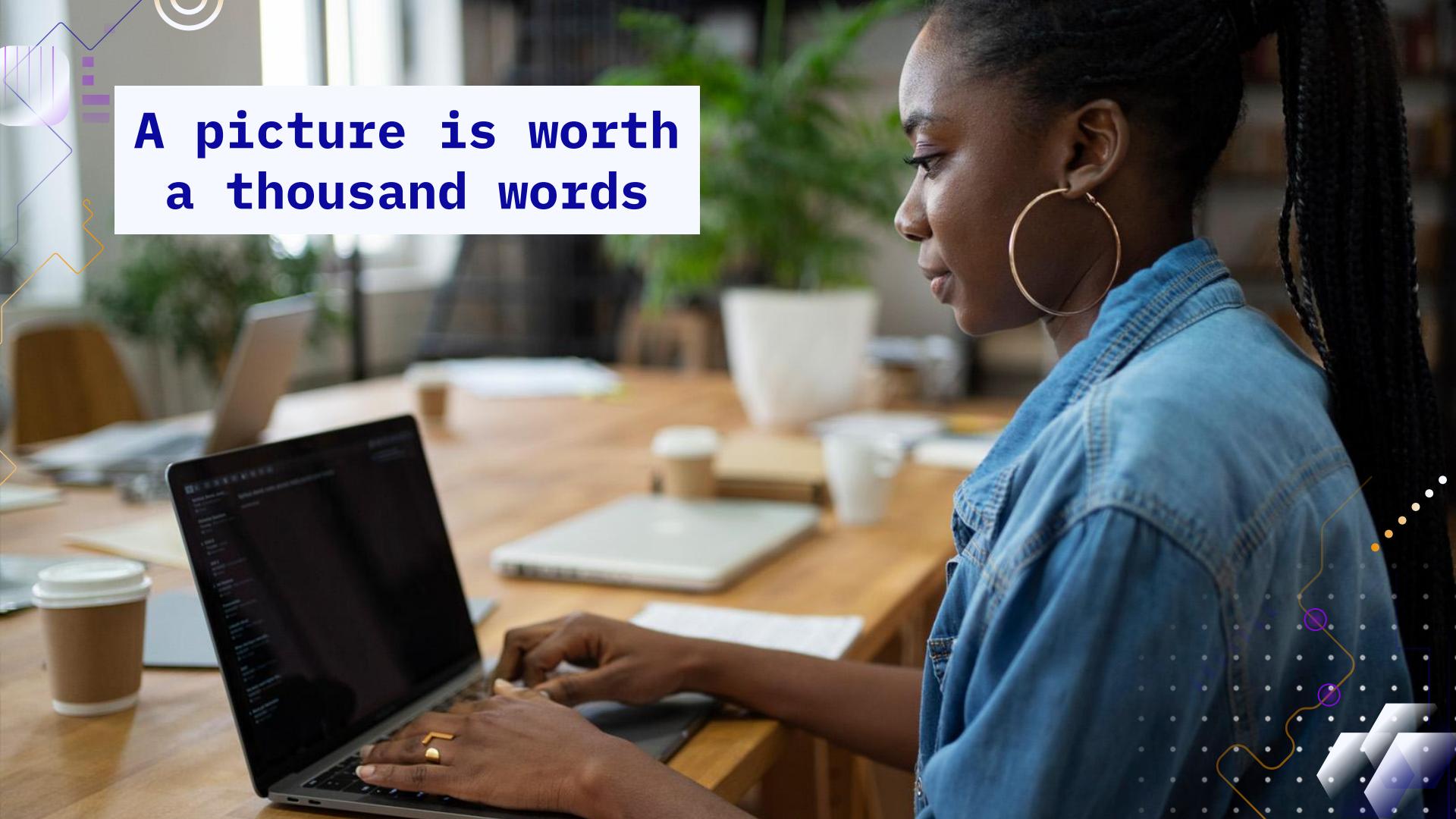
333,000

The Sun's mass compared to Earth's

386,000 km

Distance between the Earth and the Moon

Awesome words



A picture is worth
a thousand words

Practical exercise - calculator

Objective:

Introduce participants to basic coding concepts by building a **simple calculator**

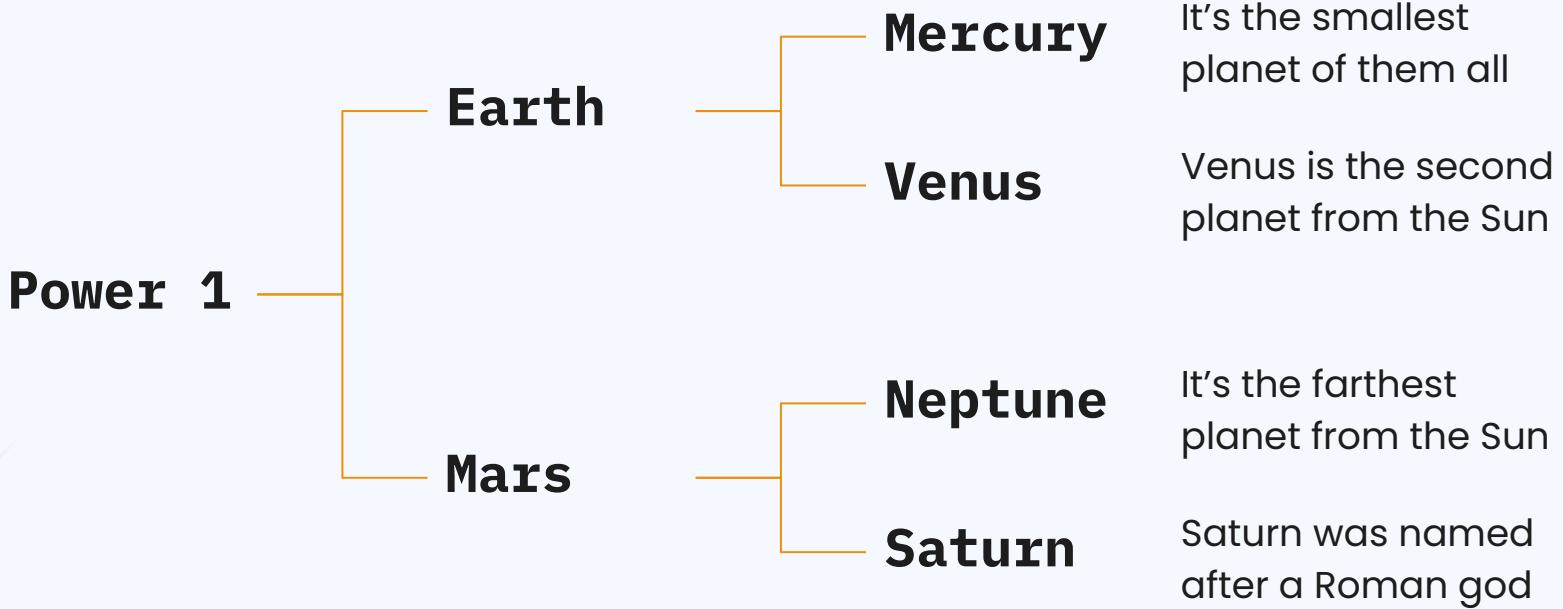
Instructions:

1. Open a Python development environment and write the following code:

```
# Simple Calculator  
num1 = int(input("Enter the first number: "))  
num2 = int(input("Enter the second number: "))  
print("Sum:", num1 + num2)  
print("Difference:", num1 - num2)  
print("Product:", num1 * num2)  
print("Quotient:", num1 / num2)
```

2. Run the program and experiment with different numbers
3. Observe the output

Brainstorm and idea generation



Main topic and details

Mars

Despite being red,
Mars is **very cold**

Jupiter

Jupiter is the biggest
planet of them all

Neptune

It's the farthest
planet from the Sun

Saturn

It's a gas giant and
has **several rings**



Popular programming languages

01

Neptune

Mercury is the closest planet to the Sun and the **smallest** of them all

02

Venus

Venus has a beautiful name and is the **second planet from the Sun**

03

Earth

Earth is the third planet from the Sun and the only one that harbors life in the Solar System

04

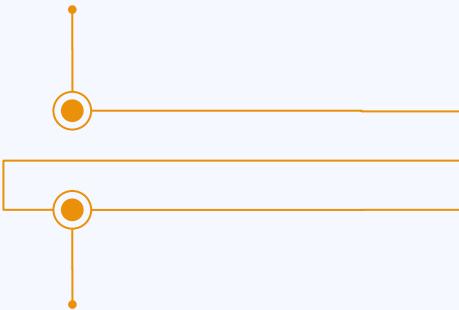
Saturn

Saturn is a gas giant and has several rings. It's composed mostly of hydrogen and helium

Sequences

Saturn is composed of
hydrogen and helium

First

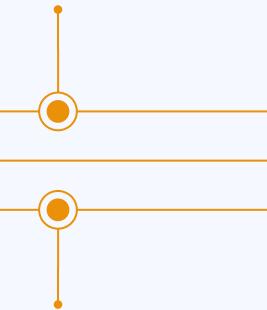


Next

Despite being red,
Mars is **very cold**

Mercury is the **closest**
planet to the Sun

Next



Next

Earth is the third
planet from the Sun

Jupiter was named
after a Roman god

Next



Last

Venus has extremely
high temperatures

Classification

Mars	Venus	Mercury	Jupiter
<ul style="list-style-type: none">• Small• Red• Cold• Rocky	<ul style="list-style-type: none">• Small• Hot• Dry• Volcanic	<ul style="list-style-type: none">• Small• Hot• Rocky• Cratered	<ul style="list-style-type: none">• Large• Cold• Gassy• Striped
Mars is full of iron oxide dust	Venus has high temperatures	Mercury is quite a small planet	Jupiter is a huge gas giant

Cause and effect

Problem

Mars

Despite being red,
Mars is very cold

Venus

Venus is the second
planet from the Sun

Solution

Mercury

Mercury is the closest
planet to the Sun

Saturn

Saturn is a gas giant
and has several rings

Question and answer

Question

Is Mercury the closest planet to the Sun and the smallest one in the Solar System? **Note that it's a bit larger than the Moon**

Answer

Venus has a beautiful name and is **the second planet from the Sun**. It's hot and has a poisonous atmosphere

Step-by-step coding

01



Earth

It's the only planet known to **harbor life**

02



Mercury

Mercury is the closest planet to the Sun

03



Jupiter

Jupiter is the **biggest** planet of them all

04



Saturn

Saturn was named after a Roman god

Parts and whole

The whole objective

Mercury is the closest planet to the Sun and the smallest one in the entire Solar System

Parts of the object

- Mercury
- Jupiter
- Venus
- Mars
- Earth
- Saturn
- Mercury

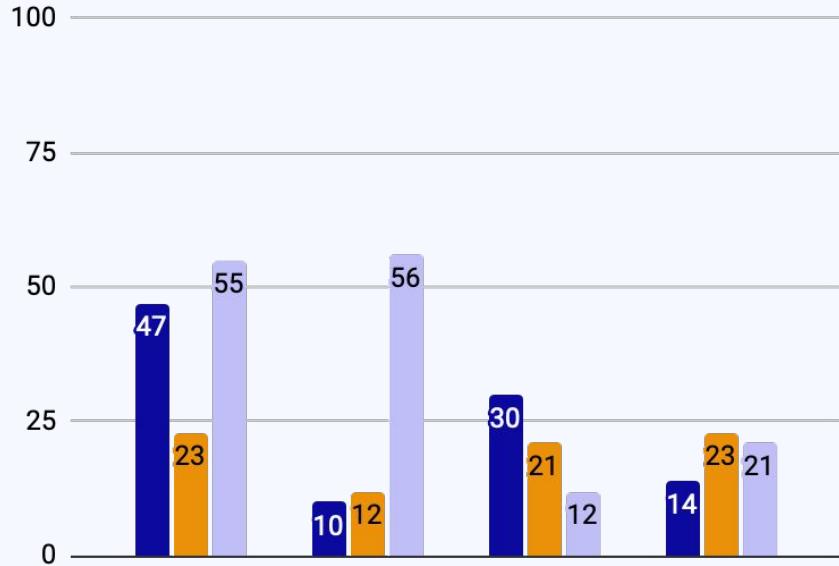
What happens if the parts are missing?

Earth is the third planet from the Sun and the **only one that harbors life in the Solar System**

What's the function of the parts?

Jupiter is a gas giant and the biggest planet in the Solar System

You can use this graph



Follow the link in the graph to modify its data and then paste the new one here. [For more info, click here](#)



Mercury

Mercury is the closest planet to the Sun



Jupiter

Jupiter is the biggest planet of them all



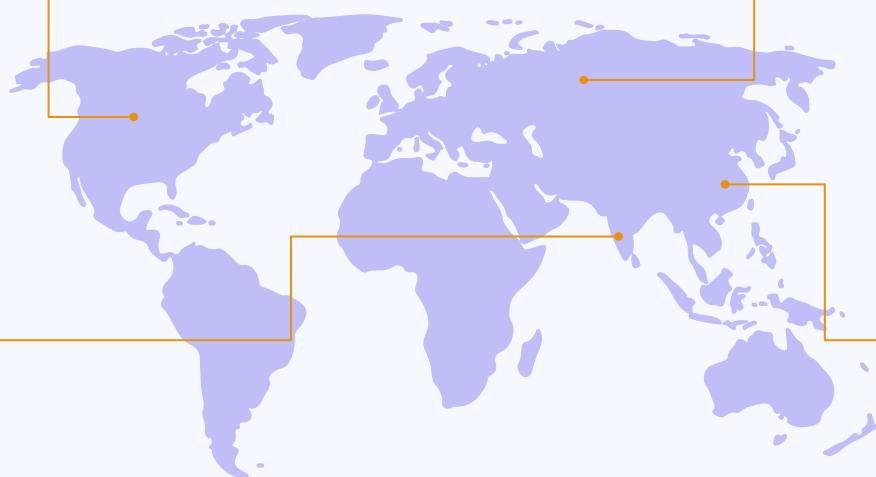
Saturn

Saturn was named after a Roman god

This is a map

USA
Despite being red, Mars is **very cold**

India
Jupiter is the biggest planet of them all



Russia

Neptune is the farthest planet from the Sun

China

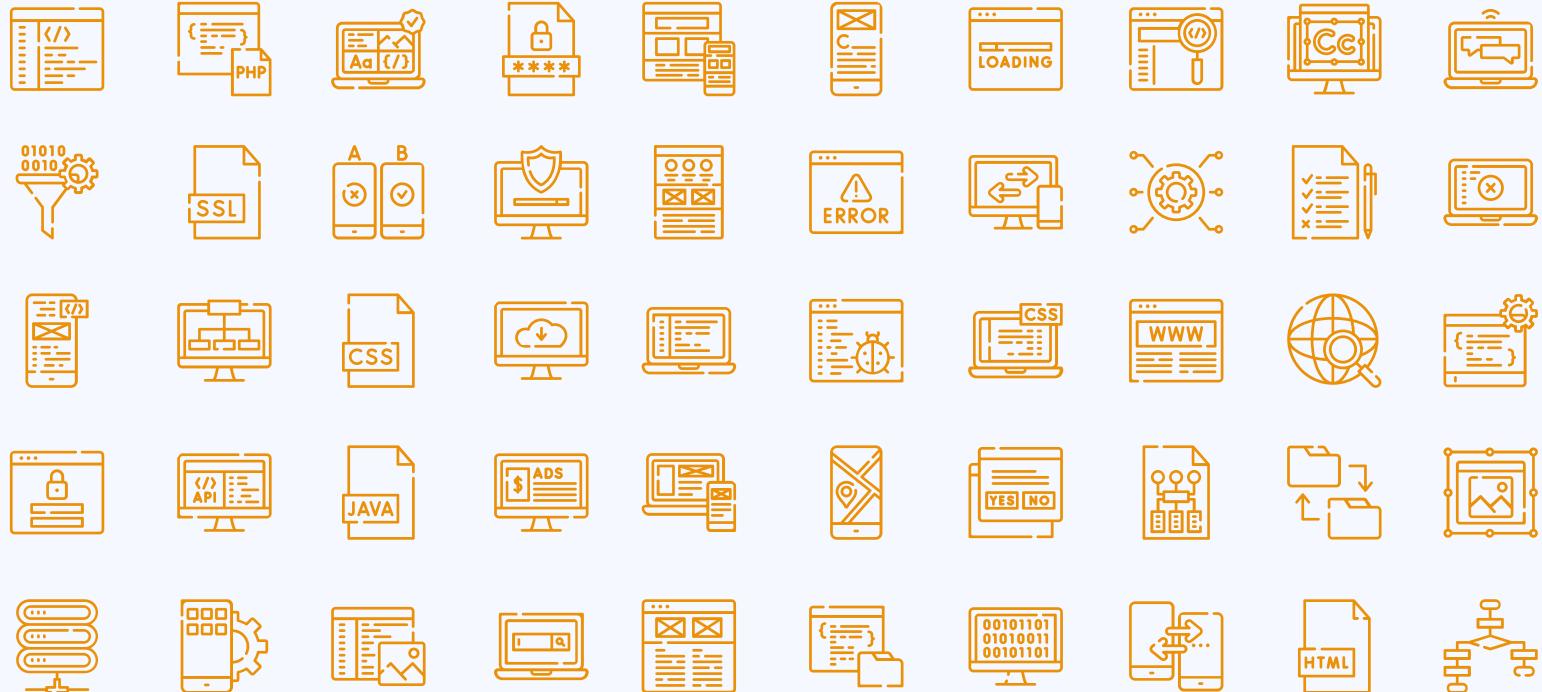
Saturn is a **gas giant** and has several rings

Mockups

You can replace the images on the screen with your own work. Just right-click on them and select “Replace image”

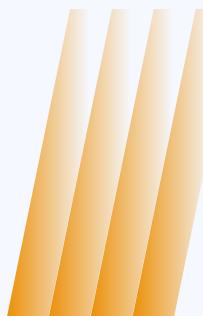
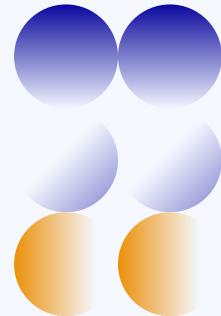
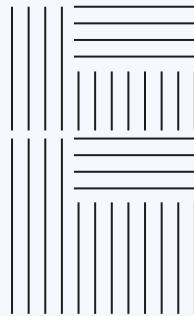


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#eb9109

Storyset

Create your Story with our illustrated concepts. Choose the style you like the most, edit its colors, pick the background and layers you want to show and bring them to life with the animator panel! It will boost your presentation. Check out [how it works](#).



Pana



Amico



Bro



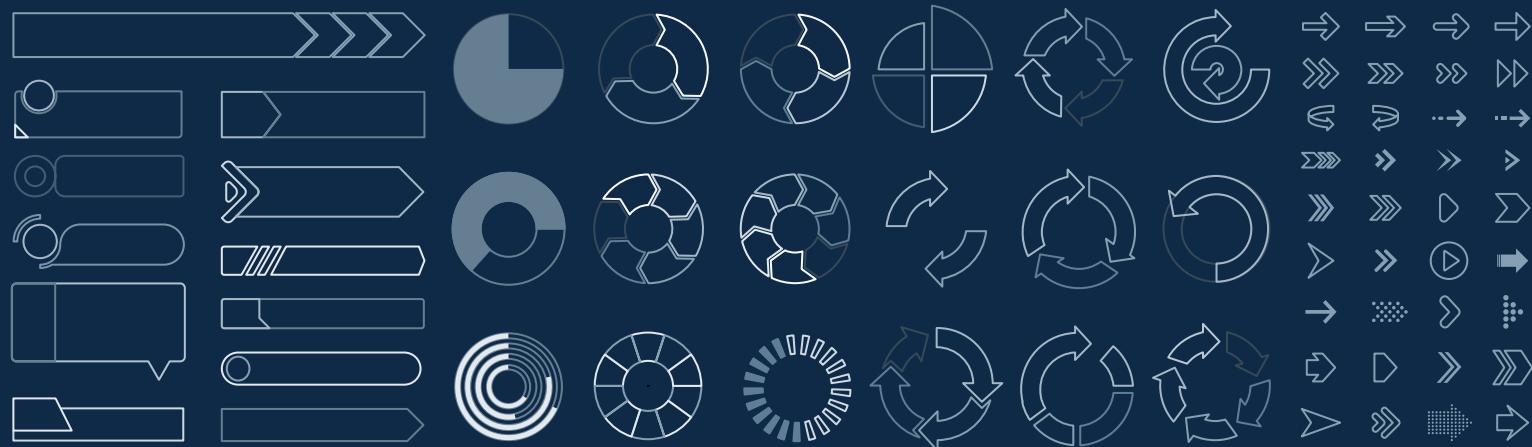
Rafiki



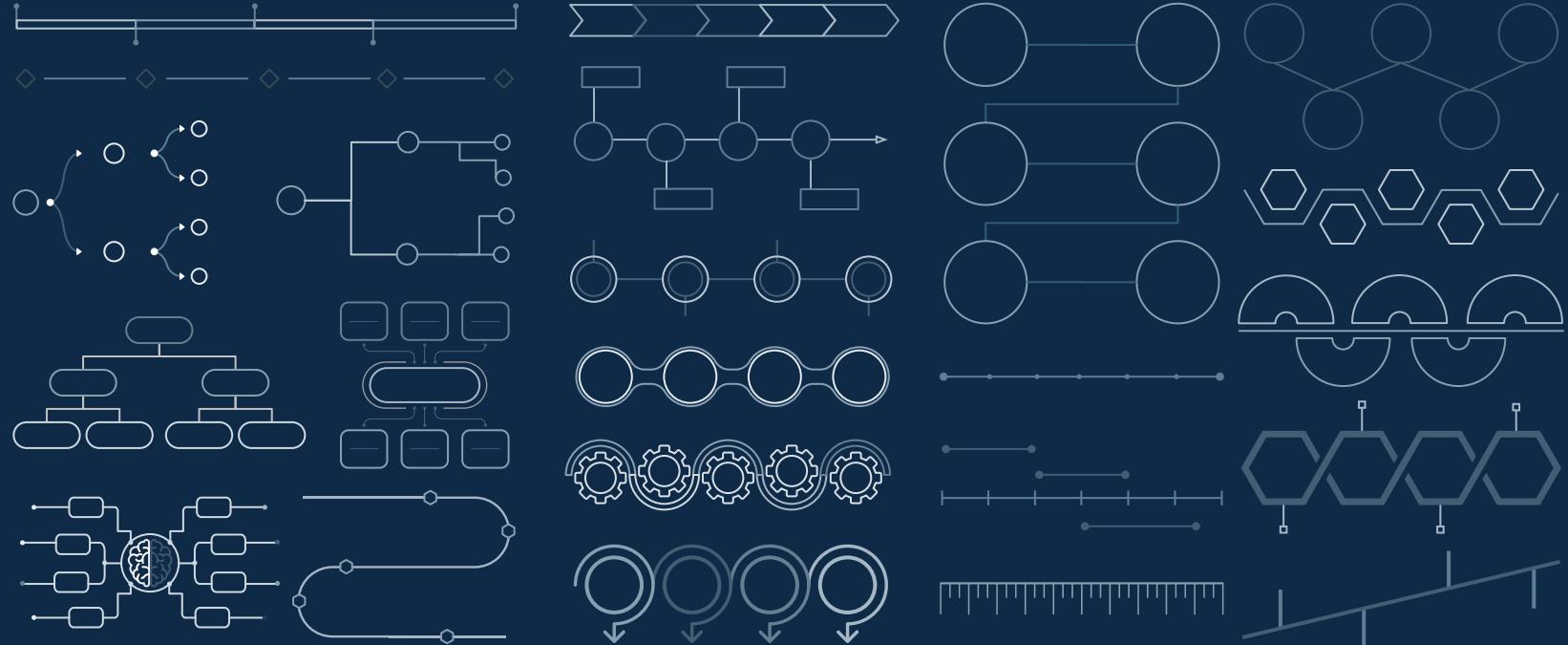
Cuate

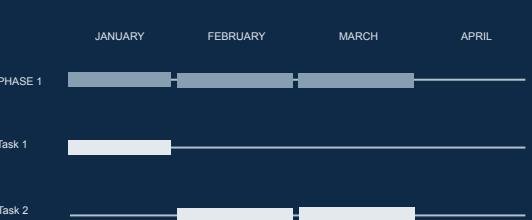
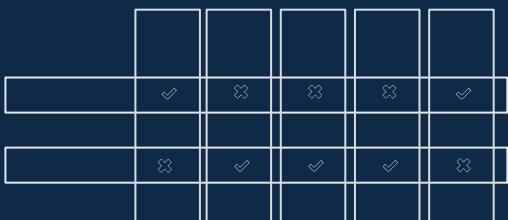
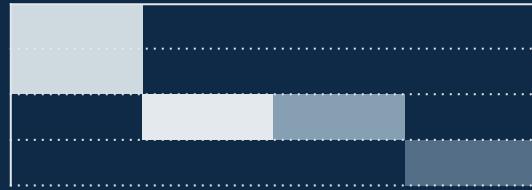
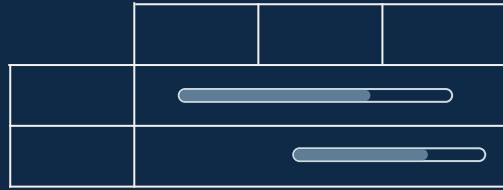
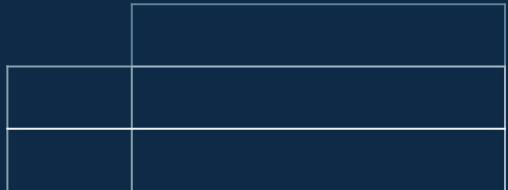
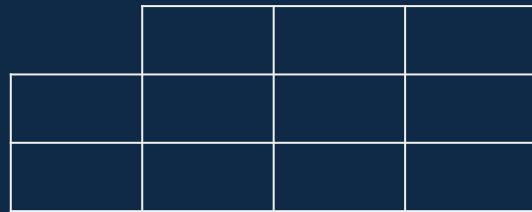
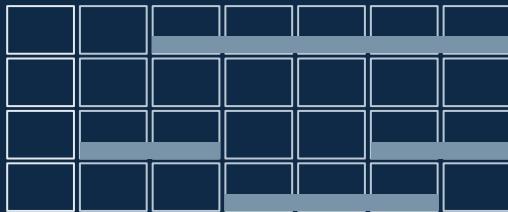
Use our editable graphic resources...

You can easily **resize** these resources without losing quality. To **change the color**, just ungroup the resource and click on the object you want to change. Then, click on the paint bucket and select the color you want. Group the resource again when you're done. You can also look for more **infographics** on Slidesgo.

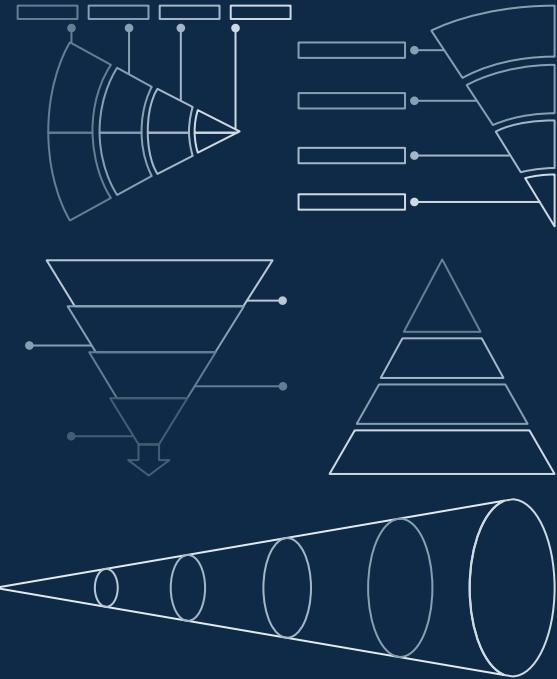
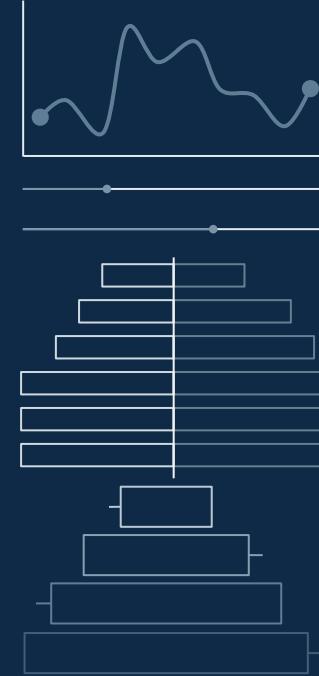
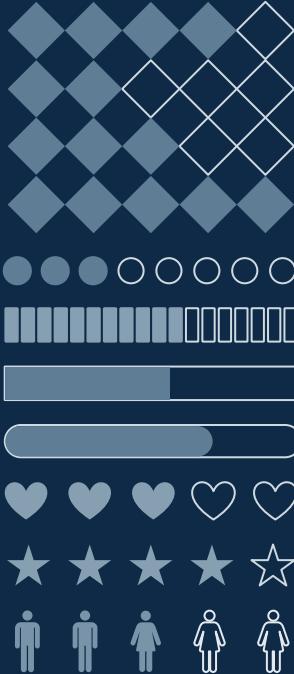
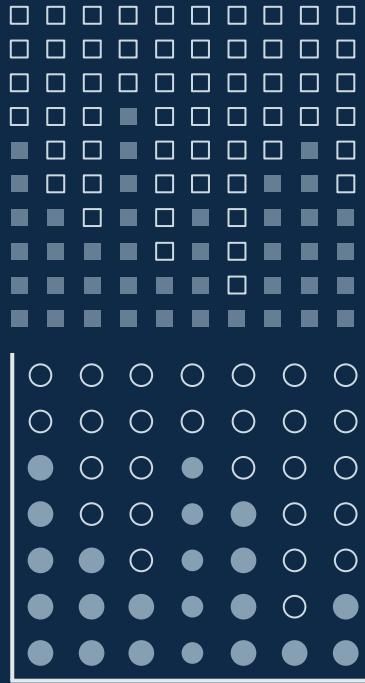












...and our sets of editable icons

You can **resize** these icons without losing quality.

You can **change the stroke and fill color**; just select the icon and click on the **paint bucket/pen**.

In Google Slides, you can also use **Flaticon's extension**, allowing you to customize and add even more icons.



Educational Icons



Medical Icons



Business Icons



Teamwork Icons



Help & Support Icons



Avatar Icons



Creative Process Icons



Performing Arts Icons



Nature Icons



SEO & Marketing Icons



