THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

GRADUATE SCHOOL
研究生院

Undergraduate Research and Innovation Scheme (URIS)

☑ Progress Report

☐ Completion Report

(*Please tick "√" as appropriate)*

Section A: The Project and Project Team

1. Project Title

AI (Artificial Intelligence) fireguard: an AI-Driven Fire Prevention System with Advanced Monitoring, Data Analytics, and Computer Vision

Project ID P0053535 **Work Programme** TAG3

2. Project Team

Name	Department	Role
Yuan Haoming	DSAI	Student
Tsang Yuen Hong	AP	Chief Supervisor
		Co-supervisor *(if any)*

3. Project Duration

	Original	Revised	Approval Date of Change Request (Mandatory)
Project Start Date	12.Oct.2024		
Project Completion Date			
Duration (*in months*)	7		

Section B: Report on Project Progress

4. Summary of Objectives Achieved

Objectives as per Proposal	Percentage Achieved (Estimated)
1. Collecting images and label them to be used in machine learning process.	50%
2. Deploy yolov5 and train the model successfully detect the obeject.	100%
3. Remotely deploy yolov5 using the camera to detect fire and smoke.	50%
3. Designing a program which can generate the optimal escape plan considering parameters such as population distribution, possible routes etc.	100%

5. Research Activities

Introduction

Cigarette smoking is a significant public-health issue, which has numerous negative impacts on health consequences such as cancer and heart disease. In addition, the fire risk is associated with smoking: discarded cigarette butts and smoldering ashes are a common ignition for residential fire. Therefore, our project aimed to develop a cigarette smoking detection model using YOLOv5 architecture. In this report, we will analyze our project process and results and provide improvement of the model. This repository contains the code for tracking and detecting fires and smokes in real-time video using YOLOv5. The project uses a pre-trained YOLOv5 model to identify the presence of fire and smoke in a given video frame and track it through subsequent frames.

a) Progress made during the reporting period

1. Dataset

Images source	Numbers
Roboflow	60%
Google images	40%

Collection	Number of images	Target	Annotation
Train	1196	smog and cigarette	different smoking angles and the smoke produced by fires
Valid	2008	smog and cigarette	random sampling ensures diverse scenarios
Test	511	smog and cigarette	no intersection with train images

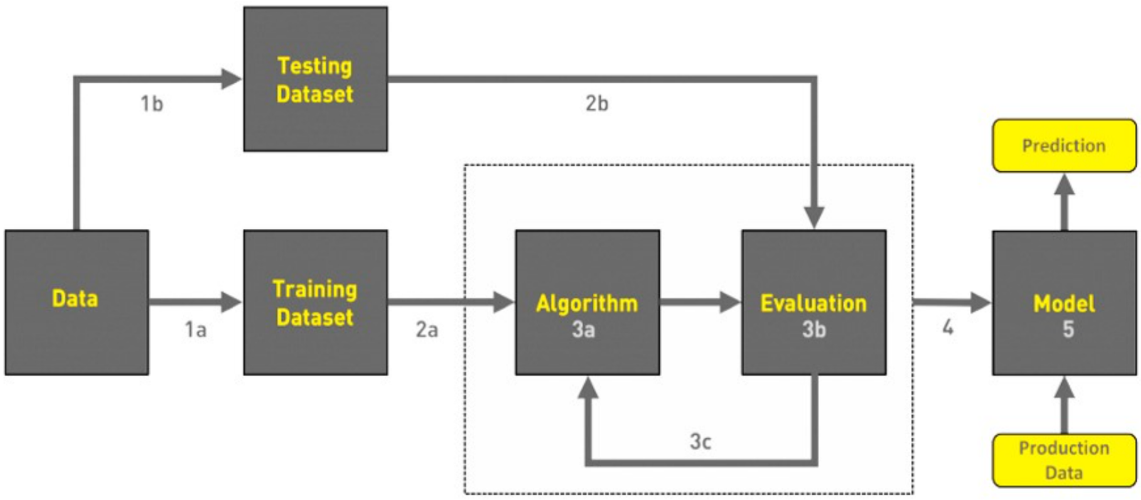
(data yaml: names: 0 cigarette 1 face-cigarette-smoking nc:3, image size 416x416)

2. Procedure

1. Install YOLOv5
2. CLI Basics
3. Roboflow Universe
4. Preparing a custom dataset
5. Custom Training

6. Validate Custom Model
7. Inference with Custom Model

Project Workflow



-> Gathering data
-> Data pre-processing
-> Researching the model that will be best for the type of data
-> Training and testing the model
-> Evaluation

```
# Base ------------------------------------------------------------------------
gitpython>=3.1.30
matplotlib>=3.3
numpy>=1.23.5
opencv-python>=4.1.1
pillow>=10.3.0
psutil  # system resources
PyYAML>=5.3.1
requests>=2.32.2
scipy>=1.4.1
thop>=0.1.1  # FLOPs computation
torch>=1.8.0  # see https://pytorch.org/get-started/locally (recommended)
torchvision>=0.9.0
tqdm>=4.66.3
ultralytics>=8.2.34  # https://ultralytics.com
# protobuf<=3.20.1  # https://github.com/ultralytics/yolov5/issues/8012

# Logging ---------------------------------------------------------------------
# tensorboard>=2.4.1
# clearml>=1.2.0
# comet

# Plotting --------------------------------------------------------------------
pandas>=1.1.4
seaborn>=0.11.0

# Export ----------------------------------------------------------------------
# coremltools>=6.0  # CoreML export
# onnx>=1.10.0  # ONNX export
# onnx-simplifier>=0.4.1  # ONNX simplifier
# nvidia-pyindex  # TensorRT export
# nvidia-tensorrt  # TensorRT export
# scikit-learn<=1.1.2  # CoreML quantization
# tensorflow>=2.4.0,<=2.13.1  # TF exports (-cpu, -aarch64, -macos)
# tensorflowjs>=3.9.0  # TF.js export
# openvino-dev>=2023.0  # OpenVINO export

# Deploy ----------------------------------------------------------------------
setuptools>=70.0.0 # Snyk vulnerability fix
# tritonclient[all]~=2.24.0

# Extras ----------------------------------------------------------------------
# ipython  # interactive notebook
# mss  # screenshots
# albumentations>=1.0.3
# pycocotools>=2.0.6  # COCO mAP
```

Fig.1 environmental requirements

1) create a new file inside the YOLOv5, this is used to store the dataset
2) configure data.yaml
3) train the model (Because we have limited computational power on personal computers, we did other implementations of combinations of batch and epoch as well. The batch and epoch are smaller in other experiments.)

YOLOv5 Implementation Code

```
# Check GPU status
!nvidia-smi

# Clone YOLOv5 repository
!git clone https://github.com/ultralytics/yolov5

# Install dependencies
!pip install -r requirements.txt
!pip uninstall wandb -qy  # Remove deprecated dependency

import torch
from IPython.display import Image, clear_output
print(f'Setup complete. Using torch {torch.__version__}')
```

Listing 1: Environment Setup

```
# Roboflow integration
!pip install roboflow

from roboflow import Roboflow
rf = Roboflow(api_key="GRuF7VlI4fgSKCtmX0n8")
project = rf.workspace("leo-there").project("smoke-and-cigarette")
dataset = project.version(1).download("yolov5")
```

Listing 2: Dataset Configuration

```
# Training parameters configuration
!python train.py \
  --img 416 \
  --batch 16 \
  --epochs 25 \
  --data /content/smoke-and-cigarette-1/data.yaml \
  --weights yolov5s.pt \
  --name yolov5s_results \
  --cache
```

Listing 3: Model Training

Visualization Code

```
# Install utilities and display results
!pip install utils
from yolov5.utils.plots import plot_results

# Display training metrics
Image(filename='/content/yolov5/runs/train/yolov5s_results2/results.png', width=1000)

# Show validation labels
Image(filename='/content/yolov5/runs/train/yolov5s_results2/val_batch0_labels.jpg',
    width=900)
```

Listing 4: Result Visualization

Compilation Notes

- Requires Python 3.8+ environment with CUDA support
- Requires 10GB+ GPU memory (Tested on NVIDIA RTX 4080)
- Roboflow API key must be replaced for dataset access
- Training time: 45 minutes (25 epochs)

image	416 x 416
Batch	16 images
Epoch	25 rounds
Pre-training weight	yolov5s.pt
equipment	RTX 4080 Laptop GPU

3 Experiment results

3.1 Data analysis

mAP@0.5: measure the degree of overlap between the predicted bounding box of the model and the actual bounding box setting the loU threshold at 0.5.
mAP@0.5:0.95: similar with mAP@0.5, is on IoU from 0.5 to 0.95 calculated mean value.

$$IoU = \frac{Area\ of\ Overlap}{Area\ of\ Union}$$

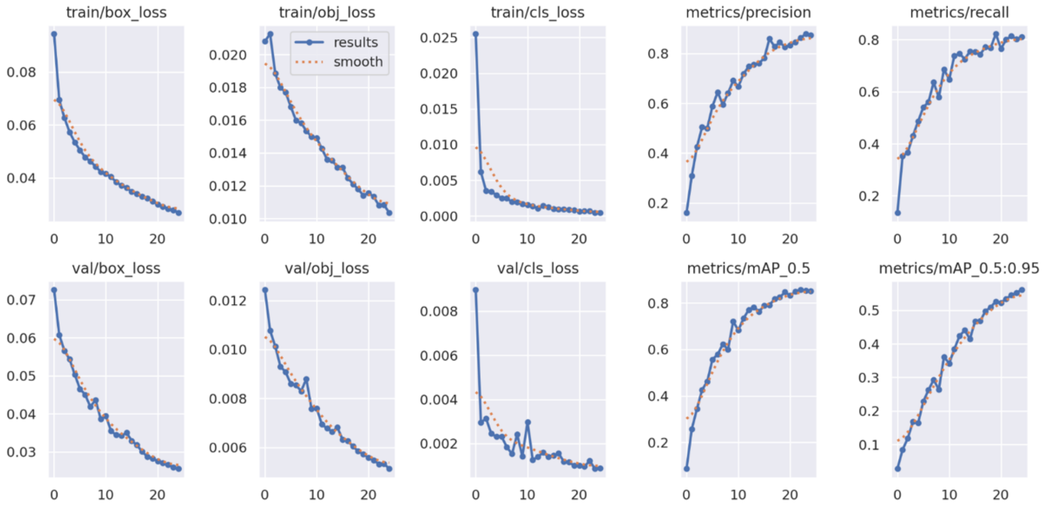


Fig.2. Results

After 25 epochs,

val/cls_loss	0.00088694
val/obj_loss	0.0051253
val/box_loss	0.81015
mAP@0.5	0.8506
mAP@0.5:0.95	0.5617

The model's loss curve shows a consistent, monotonic decline across all components(box/obj/cls). Each drop sharply during the first 5-10 epochs and then gradually decrease their minima by epoch 25, with the validation losses closes tracking the training loss (no significant emerges). In addition, the mAP@0.5 has a steady rise from ~0.00 to ~0.85 and mAP@0.5:0.95 climb smoothly from ~0.00 to ~0.56. This indicates the smooth convergence of both loss and mAP shows that the effective learning without overfitting and the model could accurately detect the object with mAP@0.25 (0.8506).

3.2 Threshold analysis

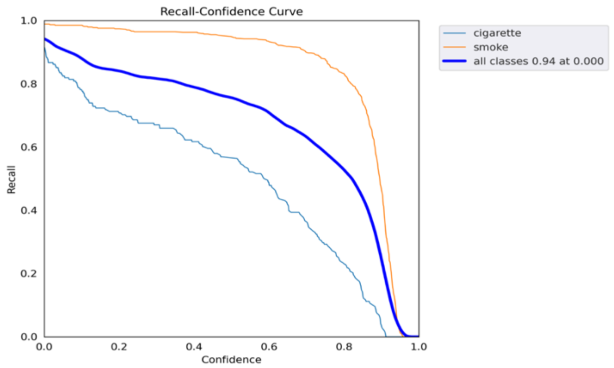


Fig.3.Recall-Confidence Curve

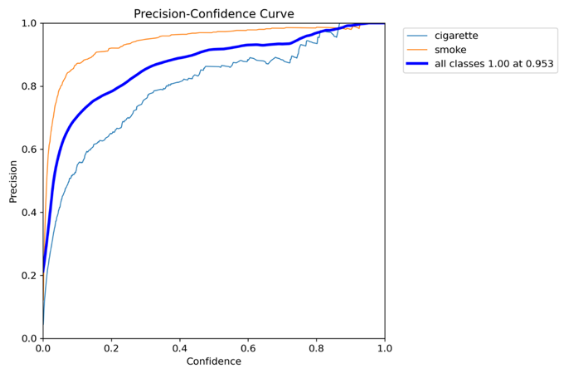


Fig.4.Precision-Confidence Curve

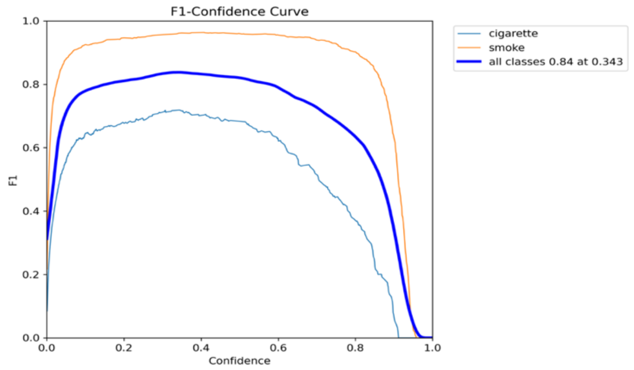


Fig.5.F1-Confidence Curve

Recall: the proportion is that predicted True by the model among all real positive samples
The Recall is highest (0.94) when the confidence threshold set as 0. The overall recall gradually decreased for threshold ranging from 0.00 to 0.85 and dropped sharply for threshold ranging from 0.85 to 0.

Precision: the proportion is that predicted True by the model among all the boxes.

The maximum precision value is 1.00 when the confidence threshold set as 1.00. the predicted probability increased rapidly when the threshold varies between 0.00 and 0.10 and increase gradually from 0.10 to 1.00.

According to F1 formula,

$$F1 = \frac{2 \times Precision\ \times Recall}{Precision + Recall}$$

the F1-confidecne reach maximum 0.84 at a confidence threshold of 0.343. As shown in Figures 3 and 4, between confidence values of 0.00 and 0.15, precision rises rapidly while recall decreased only slightly, causing F1 score to increase. From 0.15 to 0.343 both Precision and Recall improve slowly which further boost F1; Beyond 0.343 up to 0.80, Recall falls faster than precision increase, so F1 decreases. Finally, the precision increased slowly, and recall decreased rapidly from 0.80 to 1.0. therefore, 0.343 is a balanced point to set the confidence threshold, simultaneously ensuring high precision while also avoiding missed detection targets.

3.3 Precision-Recall

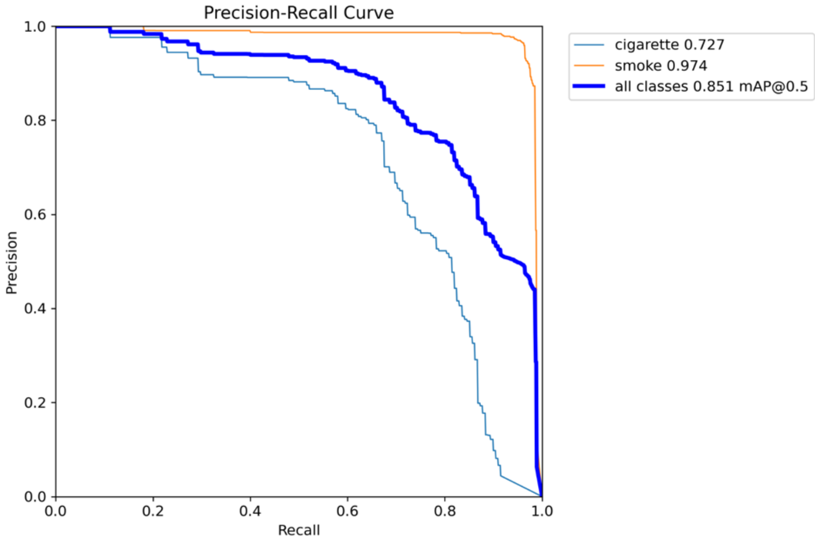


Fig.6.Precision-Recall Curve

The Figure 6 shows the mean Average Precision at IoU threshold on 0.5. The model attain mAP@0.5 of 0.851 including of cigarette AP=0.727 and smoke AP=0.974, showing the good fitting of the model.

3.4 Confusion matrix

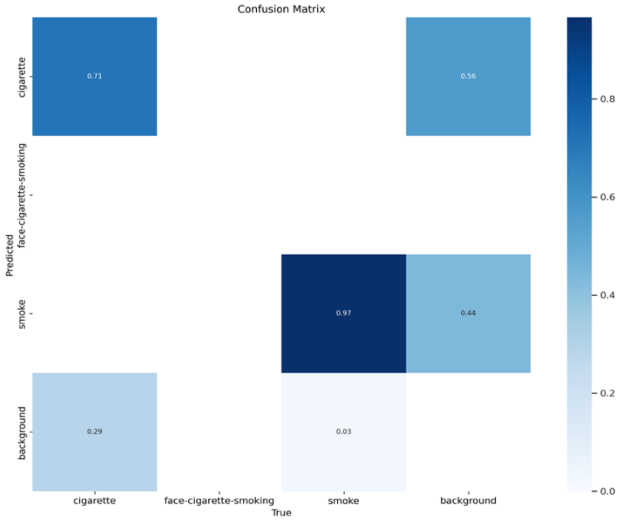


Fig.7 The confusion matrix of object (without face-cigarette-smoking data)

	Predicted True	Predicted False
Actual True	TP	FN
Actual False	FP	TN

According to Recall formula,

$$Recall = \frac{TP}{TP + FN}$$

According to Precision formula,

$$Precision = \frac{TP}{TP + FP}$$

According to Confusion Matrix, 97% of smoke instances are correctly detected with a miss rate of 3%, demonstrating excellent performance on large, diffuse targets. In contrast, only 71% of cigarette target are detected, and among 30% of cigarette could not be detected correctly, likely due to the small size of the object, hand occlusion, and similar color to the cigarette light. conditions. Moreover, 44% of background regions are mistakenly recognized as smoke and 56% of background regions are mistakenly recognized as cigarette. This is because some backgrounds such as fog or white color, are similar to the texture of “smoke” and “cigarette” and recognize as high false positives.

3.5 Case analysis

Listing 1: Implementation.py

```python
import sys
import os
import cv2
import torch
import pathlib

# Critical path correction -----------------------------------------------
BASE_DIR = os.path.dirname(os.path.abspath(__file__))
YOLOV5_PATH = os.path.join(BASE_DIR, 'yolov5')
sys.path.insert(0, YOLOV5_PATH)  # Must be placed before other imports

# Temporarily redirect PosixPath to WindowsPath
temp = pathlib.PosixPath
pathlib.PosixPath = pathlib.WindowsPath

from yolov5.models.experimental import attempt_load
from yolov5.utils.general import non_max_suppression, scale_boxes
from yolov5.utils.plots import Annotator, colors
# ------------------------------------------------------------

def main():
    # Load model
    model = attempt_load(os.path.join(BASE_DIR, 'best.pt'), device='cpu')
    model.eval()

    # Initialize camera
    cap = cv2.VideoCapture(0)
    cap.set(cv2.CAP_PROP_FRAME_WIDTH, 640)
    cap.set(cv2.CAP_PROP_FRAME_HEIGHT, 480)

    try:
        while True:
            ret, frame = cap.read()
            if not ret:
                break

            # Preprocessing
            img_rgb = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
            img_tensor = torch.from_numpy(img_rgb).permute(2, 0, 1).float().
                div(255.0).unsqueeze(0)

            # Inference
            with torch.no_grad():
                pred = model(img_tensor)[0]

            # Post-processing
            pred = non_max_suppression(pred, conf_thres=0.5, iou_thres=0.5)

            # Draw results
            annotator = Annotator(frame)
            if pred[0] is not None:
                det = pred[0]
                det[:, :4] = scale_boxes(img_tensor.shape[2:], det[:, :4],
```

```
                                frame.shape).round()
                            for *xyxy, conf, cls in reversed(det):
                                label = f'{model.names[int(cls)]} {conf:.2f}'
                                annotator.box_label(xyxy, label, color=colors(int(cls)))

                # Display frame
                cv2.imshow('Fire Detection', annotator.result())
                if cv2.waitKey(1) & 0xFF == ord('q'):
                    break
        finally:
            cap.release()
            cv2.destroyAllWindows()

        # Restore original PosixPath
        pathlib.PosixPath = temp

if __name__ == "__main__":
        main()
```

Figure 8 on the left side is used to validate the model's accuracy, and Figure 9 on the right shows the detection results produced by the model. Most of images are detected correctly, with recall rate of 0.9375 and average confidence of 0.794. In addition, for the picture in the third column of the fourth row, which do not mark the cigarette, but the model detects it. Therefore, the model has achieved reliability in most detections, but there is still room for improvement in the detection precision and recall rate of "small targets" cigarettes.

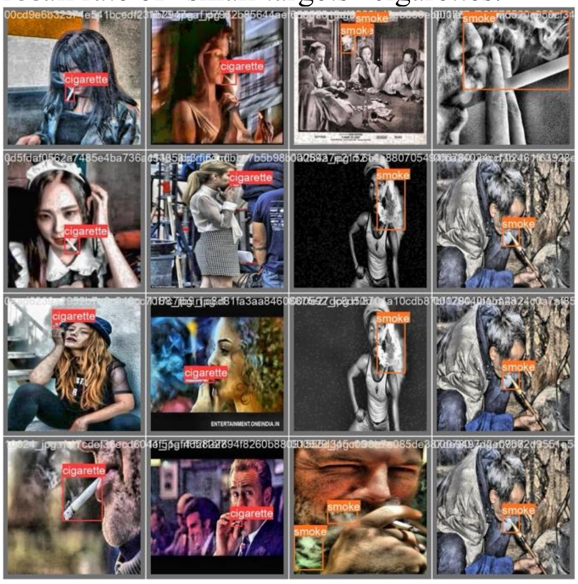


Fig.8. val_batch2_labels

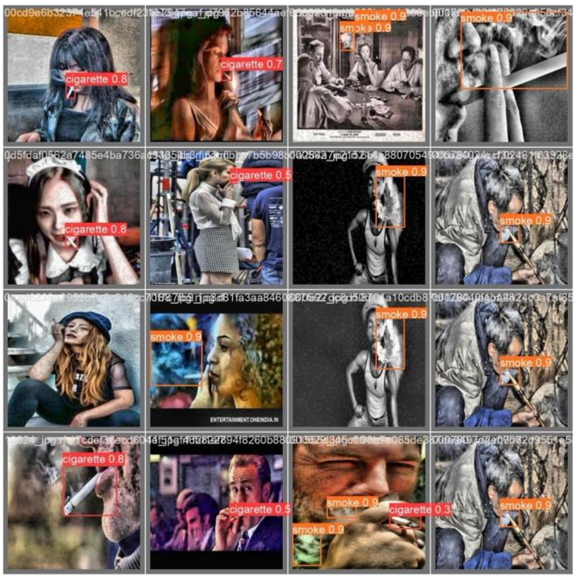


Fig.9.val_batch2_preds

3.6 Difficulties encountered during the reporting period

1, There are 2890 pictures, test 284, train 2007, valid 596. There are numbers of images to label.
2, During the process of training the model, incorrect environment variables were encountered.
3, Improve the accuracy rate of the model

3.7 In conclusion and future work

The model has achieved reliability on the smoke detection ($AP_{smoke} = 0.974$), with precision and recall keeping above 0.9 at the F1 peak of 0.96, indicating most of correct objects. In contrast, cigarette detection is relatively less robust ($AP_{cigarette} = 0.727$), reaching an F1of 0.70 at precision ≈ 0.7 and recall ≈ 0.65, increasing the confidence threshold to reduce false positives drops cigarette recall below 0.5, but decreasing it to achieve recall >0.9 causing a surge in low precision. The overall mAP@0.5 =0.851 and mAP@0.5:0.95 = 0.561 demonstrates a good general fire smoke detection quality. However, there is still room for improvement in the accuracy of cigarette. In the future work, small-object detection will be further refined by augmenting the training set with cigarette images from diverse viewpoints and under varied lighting conditions. In addition, an alert device will be developed to automatically detect flammable materials and notify security, formulating the escape route in case of fire in the building.

6. **Project Outputs** *(Completion report should include the outputs previously reported in the progress report)*

a) List of publications and other scholarly output

Status (accepted/ published)	Journal	Author List	Publication Title (also provide the hyperlink of the published paper)

b) List of competitions or awards

Date	Competition/Award	Organizer	Result (also provide the hyperlink of competition/ award)

c) List of conferences attended with presentation

Date	Conference	Organizer	Presentation Title (also provide the hyperlink of conference)

d) Innovation and technology development
(e.g. source codes, applications, prototypes)

https://github.com/Llleeeo/Smoke-and-Fire-detection-model-and-implementation-
please visit this website link to find complete implementation code, parameter and weights after training, and yolov5 training code.

Note: Please insert more rows as necessary.

Section C: Declaration

7. Declaration by the Student

☑ I DECLARE the research project is my original work except for source material explicitly acknowledged; and I UNDERTAKE to maintain the highest ethical standard and academic integrity throughout the research. I am aware I will be held responsible for any disciplinary actions.

☐ I DECLARE the research project has not been submitted for more than one purpose, such as an assignment for another course. I understand that the URIS project may be a precursor to a final-year project (FYP). I acknowledge that it should not form part of the FYP or contribute to its grade.

Name: Yuan Haoming Signature: Yuan Haoming Date: 14/05/2025

Section D: Rating and Endorsement by Chief Supervisor

8. Rating and Comments

a) Overall Rating

The progress of the project is recommended as:

*outstanding/ very satisfactory / satisfactory/ unsatisfactory.

b) Comments

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9. Research Grant

Information available in Projects and Grants Management System

Balance:	HK$

☐ I DECLARE the grant is only used by student on items which are directly relevant to the project concerned. In addition, the University's prevailing purchasing policy shall be followed.

Name: ____________________ Signature: ________________ Date: _______________

Chief Supervisor

* Please delete as appropriate.

Only project rated "Outstanding" is eligible for the Best URIS Research Project Award upon project completion.

<u>Section E: Rating and Endorsement by Departmental / School Research Committee</u>

10. Rating and Comments

Note: If the Chief Supervisor is the D/SRC Chair, the FRC/School Board Chair is requested to complete this Section.

a) Overall Rating

The progress of the project is recommended as:

*outstanding/ very satisfactory / satisfactory/ unsatisfactory.

If the rating <u>differs</u> from the Chief Supervisor's rating as in Section D, please provide the reason for the difference in the comment section below.

b) Comments

____

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____

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Name: ________________________ Signature: _________________ Date: ________________
Chair, D/SRC

* Please delete as appropriate.
Only project rated "Outstanding" is eligible for the Best URIS Research Project Award upon project completion.

Section F: Approval by Undergraduate Research and Innovation Committee

11. Rating and Approval

a) Overall Rating

The progress of the project is recommended as:

*outstanding/ very satisfactory / satisfactory/ unsatisfactory.

* Please delete as appropriate.

(For GS use)

GS actions:

- ☐ Eligibility check before URIC Chair decision
- ☐ GS record updated
- ☐ Decision notice sent to student, Chief Supervisor and D/SRC Chair

Updated in Mar 2025