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Pothole Detection Using Deep Learning

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ABSTRACT

In India, the death rate due to potholes is about 30 percent annually. Potholes are in fact, really common to spot on roads, one can literally find it in every one kilometer on Indian streets. The potholes are nothing but the depression on the road surface or plain ground caused due to the cracks or erosion, they are mainly formed, or spotted during the rainy season and are unimaginably hazardous. The Ministry of Road Transport and Highways are the concerned authorities who are not yet equipped with a system that could help them to keep a track of potholes in order to reduce them. And that's where our PDS- Pothole Detection System comes into picture. It takes the video input through the camera, processes it on the Raspberry-Pi, detects and enlists the pothole with its accuracy. Along with which the GPS module tracks the coordinates of the pothole and appends it into a dataset on cloud.

The processing of pothole images is undergone through the YOLO-V5 algorithm, it is an object detection algorithm that incorporates the CNN- Convolutional Neural Networks. The dataset used here is labeled by us. The system is being fabricated and undergone manual inspection in which the detected potholes with accuracy beyond 80 percent are serious issue and needs to be treated at the earliest

Keywords - Deep Learning, Pothole detection system, YOLO-V5, Object Detection Method, CNN, Geo -Tagging

1. Introduction

Deep learning aims to satisfy all the issues and create a very efficient deep learning model to detect potholes that need to be fixed as quickly as possible. Deep learning is an emerging technology with huge benefits to common people. The research papers showed that some people have tried to implement a deep learning model to detect potholes. Although fairly efficient, these models take comparatively more time and are not used in a realtime project. The survey provided valuable information about the models that can be used along with useful tips about choosing the datasets. Models visible have efficiency of utmost 87 percent but we hope to try out some new techniques like color masking to try and get the efficiency up by a bit. Also plan to implement this in an easy to use software with daily low requirements so that it can run on low powered processors. The Motivation behind implementation of this project is to create a platform that will provide concerned authorities with an up-to-date database of potholes along with its geological coordinates. After the system is being mounted in police patrolling vans or jeeps it will track down the potholes real time and list it down into the database, which means there is no human involvement in the process and is completely hassle-free. To develop a detection system for concerned authorities for keeping them posted about potholes and their location. So they could take necessary actions at the earliest to treat them and avoid accidents or hazards.

2. Literature Survey

Volkan Kaya, Ismail Akg¨ul [1] proposed Detection Of Potholes On Highway Using Deep Learning.

This paper highlights the importance behind detection of potholes on highway and achieved this with max accuracy with the help of YOLO-V4 deep learning algorithm and trained it with 334 potholes regions on 105 images. Correct detection was made in 504 images out of a total of 576 performance test images, and a success accuracy of 87.5 percent was achieved.

Silvister, S., Komandur, D., Kokate, S., Khochare, A., More, U., Musale, V., Joshi, A. [2] proposed Deep learning approach to detect potholes in real-time using smartphone

This research introduces a system for real-time pothole detection using deep learning algorithms and smartphone integration. Deep learning algorithm for object detection The Single Shot Multibox Detector (SSD) uses a portable camera to search for potholes. Results are stable thanks to the dual method of camera-based and accelerometer-gyroscope-based detection.

Ping, P., Yang, X., Gao, Z. [3] proposed A deep learning approach for street pothole detection

This paper performs a comparative analysis upon 4 models that are : YOLO-V3, SSD, HOG with SVM and Faster-CNN. The experimental results show that the YOLO V3 model performs best for its faster and more reliable detection results.

Pereira, V., Tamura, S., Hayamizu, S., Fukai, H. [4] proposed A deep learning-based approach for road pot- hole detection in timor leste.

This research proposes a cost effective solution to detect potholes using CNN. The training dataset is of wet, dry images of potholes and testing is done over 500 images. The Output accuracy of the model turns out to be 99.80 percent.

Dhiman, A., Klette, R. [5] proposed Pothole detection using computer vision and learning.

This paper categorises developed strategies into several groups. They created and tested two techniques based on stereo-vision analysis of road environments ahead of the vehicle, as well as two deep-learning-based pothole detection models. An experimental evaluation of the four designed methods is provided, and conclusions about the specific benefits of these methods are drawn.

Dharneeshkar, J., Aniruthan, S. A., Karthika, R., Parameswaran, L. [6] proposed Deep Learning based De- tection of potholes in Indian roads using YOLO.

This paper highlights the challenge of road maintenance tasks in countries like India. It discusses about how there is a need for cost effective automated identification of potholes. In this paper, they have created a 1500 image dataset on Indian roads. The dataset is annotated and trained using YOLO. They have trained the new dataset on YOLOv3, YOLOv2, YOLOv3-tiny and compared all the results on the basis of precision and recall.

J. Dib, K. Sirlantzis and G. Howells [7] presented A Review on Negative Road Anomaly Detection Methods

This paper focuses on negative road anomalies which is the term used to refer to potholes and cracks on the surface of the road. The existing techniques are reviewed and their limitations have been highlighted and they are assessed via certain performance indicators and via some chosen criteria which are introduced in this paper.

P. A. Chitale, K. Y. Kekre, H. R. Shenai, R. Karani and J. P. Gala [8] proposed Pothole Detection and Dimension Estimation System using Deep Learning (YOLO) and Image Processings

The computer vision model library You Look Only Once version 3, also known as Yolo v3, is used in this paper to detect potholes automatically. The effects of light and weather on our ability to detect road damage are natural. These adverse conditions also have a negative impact on the performance of visual object detectors. The goal of this project was to investigate the impact of adverse conditions on pothole detection. The basic design of this study is thus divided into two parts: dataset creation and data processing, and dataset experiments using Yolo v3.

T. D. Chung and M. K. A. A. Khan [9] presented Watershed-based Real-time Image Processing for Multi-Potholes Detection on Asphalt Road

This paper describes a real-time watershed-based algorithm for detecting multiple potholes on an asphalt road surface. Before applying the watershed algorithm, the algorithm employs inverted binary in conjunction with Otsu thresholding techniques to determine the optimal threshold value of the image in an inverted colour space, followed by morphological techniques with open, then close kernels to filter small noises and bold pothole edges on the image, and distance transform to find markers on the pre-watershed-phase image. This algorithm can detect potholes of various sizes and structures on three types of road surfaces: smooth, aged, and degraded.

Adam, Edriss Eisa Babikir, and A. Sathesh. [10] proposed Construction of Accurate Crack Identification on Concrete Structure using Hybrid Deep Learning Approach.

This paper discusses several conservative techniques that are available for detecting cracks in concrete bridges but they have significant limitations, including low accuracy and efficiency. The proposed technique in this paper is more resourceful by performing classification via SVM approach, and further the feature extraction and network training has been implemented by using the CNN method. Moreover, the proposed method is determining the widths of the crack by employing binary conversion in the captured images. The proposed model outperforms conservative techniques, single type classifiers, and image segmentation type process methods in terms of accuracy. The obtained results have proved that the proposed hybrid method in this paper is more accurate and suitable for crack detection in concrete bridges especially in the unmanned environment.

Swati Shekapure, Nikita Pagar, Bhagyashree Kulkarni, Dinesh Choudhary and Priti Parkhad.[11] Predicting COVID-19 Pneumonia Severity based on Chest X-ray with Deep Learning.

The automated image based system is proposed in this paper to detect pneumonia disease. Image processing of resultant image is achieved through CNN, the image data is predicted on various features and adopts the use of AI for disease detection.

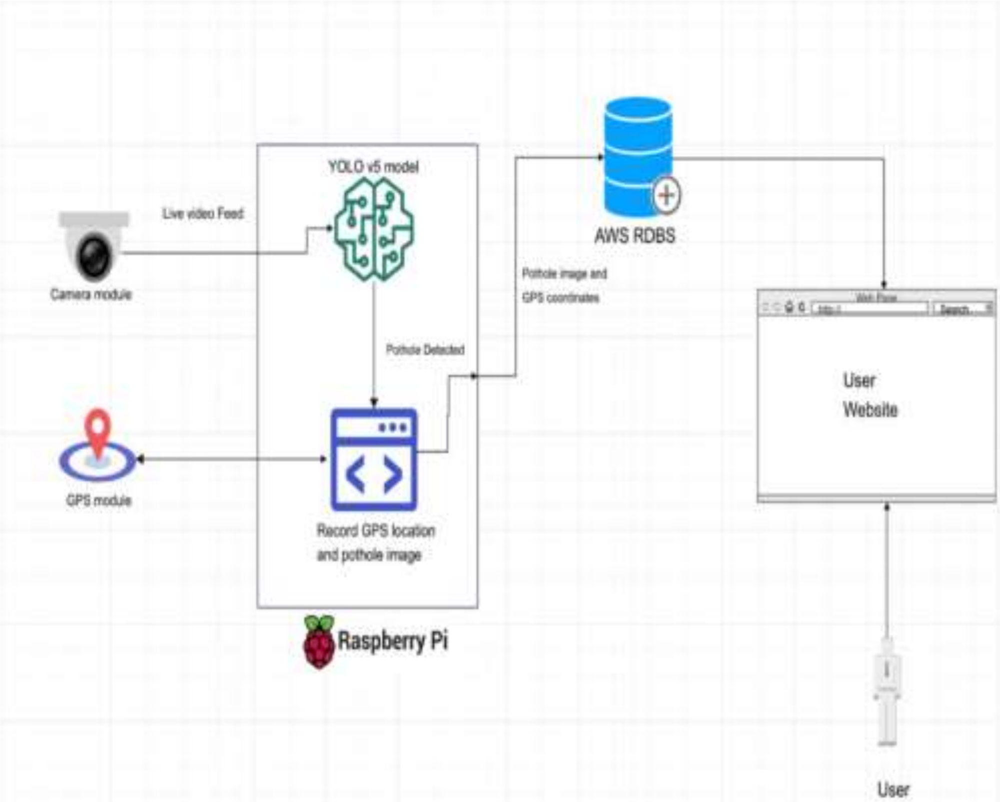
Aditi Palwe, Sankirti Shiravale, Swati Shekapure [12]. Image Captioning using Efficient Net.

This paper uses the deep learning approach to extend the image in text format. EfficientNetB3 Deep learning framework is used for this purpose, and the image processing and feature extraction is being achieved through CNN module.

3. System Architecture

3.1 System Architecture

The Detection system consists of a camera and GPS module which captures the video input of roads and location coordinates respectively. Further, the video input is then fed to YOLO- object detection Machine learning model. YOLO processes the input and detects the potholes along with which the place where the pothole is being detected is mapped with GPS and both of these details are stored into the cloud, here we are using AWS RDBMS. This execution of the entire Pothole Detection System leads to a collective comprehensive database at the user's end.



System Architecture

4. Methodology

We have used YOLO V5 (You Only Look Once) for detecting potholes in real-time. YOLO trains on full images with labeled potholes. First we take input in video format from the camera with location coordinates from the GPS module simultaneously. This video is passed to YOLO where it performs real time detection of potholes using CNN (Convolutional Neural Network). Processing is done frame by frame. Each frame (image) is divided into a grid of MxM and then it makes a prediction for each square of the grid. A confidence value is attached to each grid and the grid with the highest confidence value is chosen first and then confidence is measured for its neighbors. This process is followed until the entire pothole in the image is detected.[11] It simultaneously predicts multiple bounding boxes and class probabilities for those boxes. Output is the image (frame) with potholes detected in bounding boxes. These images with potholes detected are stored in a database with their coordinates respectively. With the help of these pothole coordinates, we will pinpoint these locations on the map and our final output will be a map with potholes pointed on it.

YOLO is an abbreviation for the term 'You Only Look Once'. This algorithm identifies and finds different things in a picture (in real-time). The class probabilities of the discovered photos are provided by the object identification process in YOLO, which is carried out as a regression problem. As the name implies, the method only requires one forward propagation through a neural network to detect objects. This means that a single algorithm run is used to perform prediction across the entire image. The CNN projects multiple class probabilities and bounding boxes at the same time. There are numerous variations of the YOLO algorithm. Tiny YOLO and YOLOv3 are two popular examples.

A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning method that can take in an input image, give various elements and objects in the image importance (learnable weights and biases), and be able to distinguish between them. Comparatively speaking, a ConvNet requires substantially less pre-processing than other classification techniques. Through the use of pertinent filters, a ConvNet may effectively capture the spatial and temporal dependencies in a picture. Because there are fewer factors to consider and the weights can be reused, the architecture provides a better fitting to the picture dataset. In other words, the network may be trained to better comprehend the level of complexity in the image.[12]

A CNN is composed of an input layer, an output layer, and many hidden layers in between.

These layers carry out operations on the data in order to discover characteristics unique to the data. Three of the most common layers are convolution, activation or ReLU, and pooling.

Convolution runs a series of convolutional filters through the input images, activating certain features of the images with each filter.

Rectified linear unit (ReLU), which maintains positive values while translating negative values to zero, enables quicker and more efficient training. Due to the fact that only the activated features are carried over to the following layer, this is frequently referred to as activation.

Pooling simplifies the output by performing nonlinear downsampling, reducing the number of parameters that the network needs to learn.Each layer learns to recognise various features as these procedures are repeated across tens or hundreds of levels.

5. Implementation

5.1. Overview of project modules

There are 4 major modules in this project namely,

1. Recording GPS coordinates. The Global Positioning System (GPS) is a satellite based navigation system that provides location and time information. It will record the coordinates and timestamp of captured pothole images.

2. Live image program to take photos at times After receiving the video input we process only that frames which spots potholes through the camera module. The image is treated as a grid of size M x M.

3. Processing in the Yolo model to detect potholes from live video We have used YOLO V5 (You Only Look Once) for detecting potholes in real-time. YOLO trains on full images with labeled potholes. First we take input in video format from the camera with location coordinates from the GPS module simultaneously. This video is passed to YOLO where it performs real time detection of potholes using CNN (Convolutional Neural Network). Processing is done frame by frame. Each frame (image) is divided into a grid of MxM and then it makes a prediction for each square of the grid. A confidence value is attached to each grid and the grid with the highest confidence value is chosen first and then confidence is measured for its neighbors. This process is followed until the entire pothole in the image is detected. It simultaneously predicts multiple bounding boxes and class probabilities for those boxes. Output is the image (frame) with pothole detected in bounding boxes These Images with potholes detected are stored in a database with their coordinates respectively.

4. Integrating hardware and software and deploying projects on cloud. With the help of these pothole coordinates, we will pinpoint these locations on the map and our final output will be a map with potholes pointed on it. And this is done on AWS at real time detection.

5.2. System Algorithm

- Trend Identification:

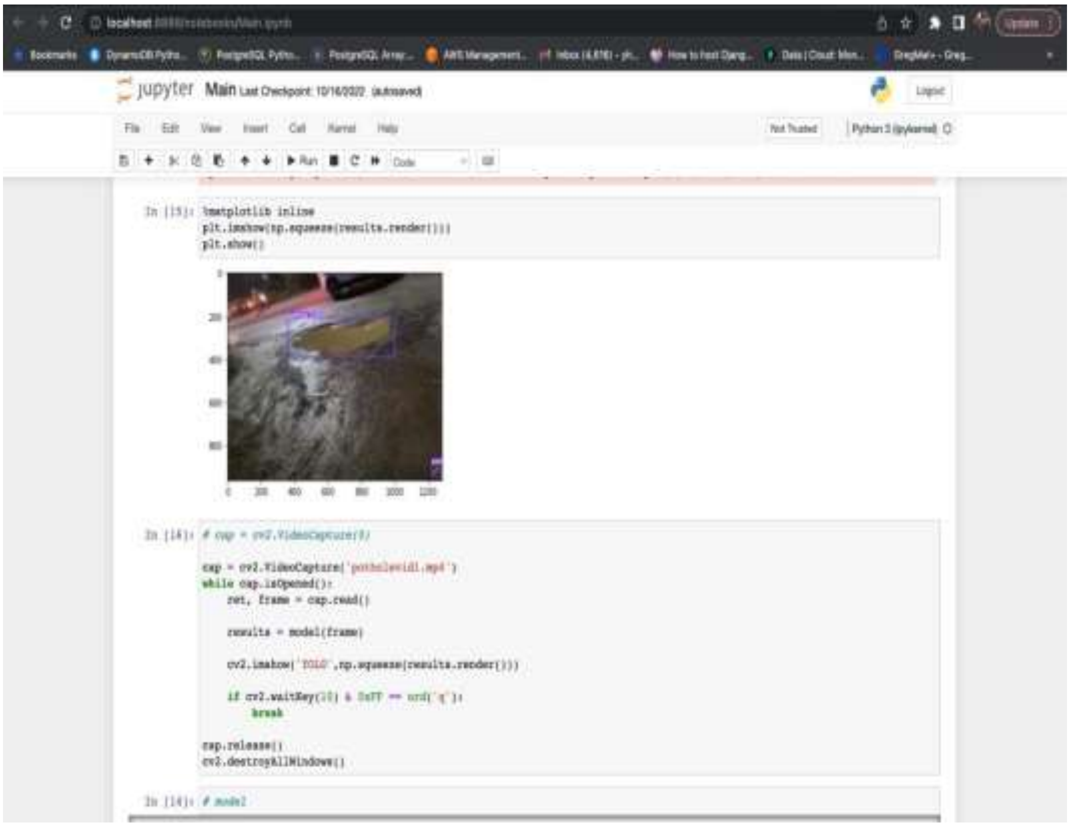
Being a decision-based algorithm, the time complexity totally depends upon the number of pixels of image that is to be processed and its confidence level.

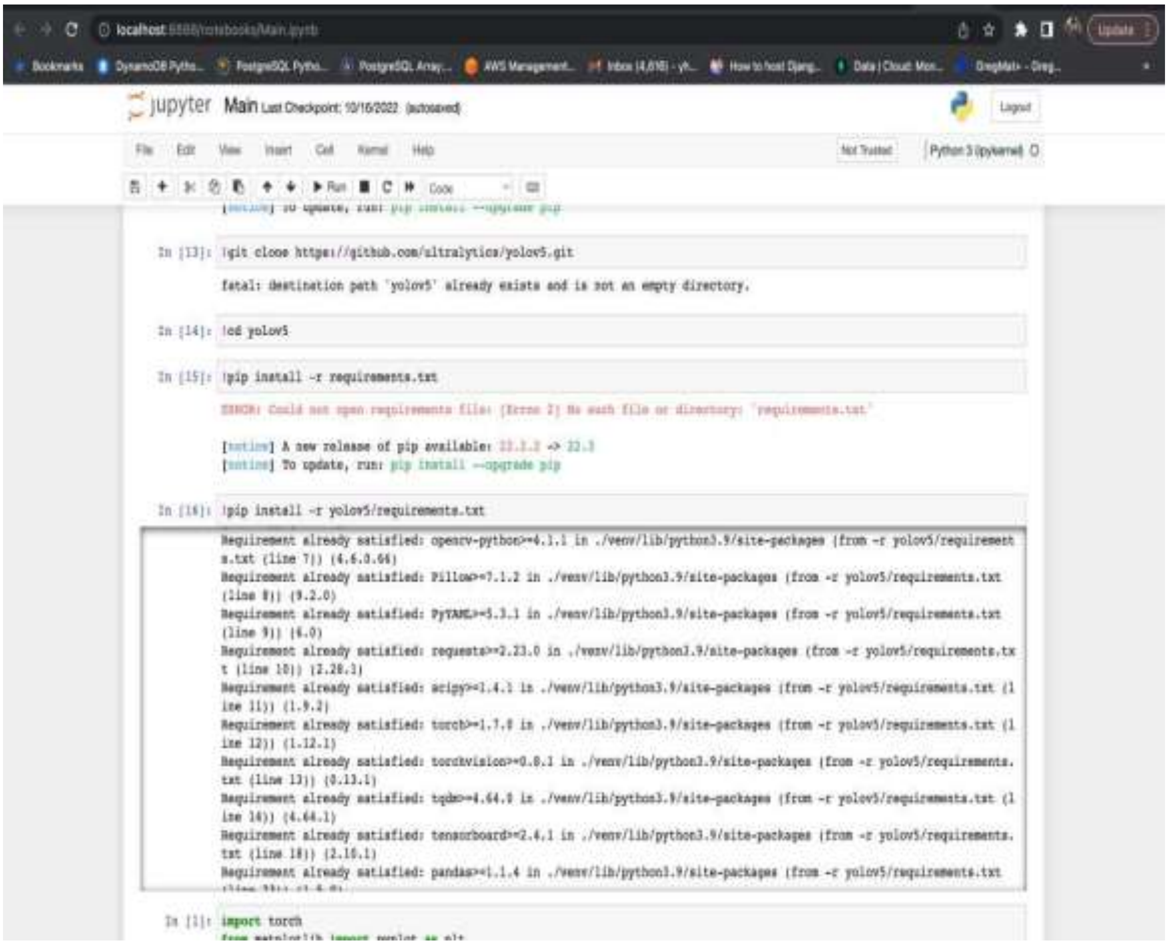
- Convolutional Neural Network (CNN):

We tried to find time complexity for training a neural network that has 4 layers with respectively i,j,k and l nodes, with t training examples and n epochs. The result was O(nt*(ij+jk+kl)).

5.3. Output

The following images show the output of our system.


jupyter Main Last Checkpoint: 10/16/2022 (autosaved)
In [15]: %matplotlib inline
plt.imshow(np.squeeze(results.render()))
plt.show()
In [14]: # cap = cv2.VideoCapture(0)
cap = cv2.VideoCapture('potholevid1.mp4')
while cap.isOpened():
ret, frame = cap.read()
results = model(frame)
cv2.imshow('YOLO',np.squeeze(results.render()))
if cv2.waitKey(10) & 0xFF == ord('q'):
break
cap.release()
cv2.destroyAllWindows()
In [14]: # model


jupyter Main Last Checkpoint: 10/16/2022 (autosaved)
In [13]: !git clone https://github.com/ultralytics/yolov5.git
fatal: destination path 'yolov5' already exists and is not an empty directory.
In [14]: !cd yolov5
In [15]: !pip install -r requirements.txt
ERROR: Could not open requirements file: [Errno 2] No such file or directory: 'requirements.txt'
[notice] A new release of pip available: 22.2.2 -> 22.3
[notice] To update, run: pip install --upgrade pip
In [16]: !pip install -r yolov5/requirements.txt
Requirement already satisfied: opencv-python>=4.1.1 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 7)) (4.6.0.66)
Requirement already satisfied: Pillow>=7.1.2 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 8)) (9.2.0)
Requirement already satisfied: PyYAML>=5.3.1 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 9)) (6.0)
Requirement already satisfied: requests>=2.23.0 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 10)) (2.28.1)
Requirement already satisfied: scipy>=1.4.1 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 11)) (1.9.2)
Requirement already satisfied: torch>=1.7.0 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 12)) (1.12.1)
Requirement already satisfied: torchvision>=0.8.1 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 13)) (0.13.1)
Requirement already satisfied: tqdm>=4.64.0 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 14)) (4.64.1)
Requirement already satisfied: tensorboard>=2.4.1 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt (line 18)) (2.10.1)
Requirement already satisfied: pandas>=1.1.4 in ./venv/lib/python3.9/site-packages (from -r yolov5/requirements.txt
In [1]: import torch

Conclusion

Our project aims to build a system that will accelerate the process of fixing potholes which will in turn save daily commuters valuable time and also damage to their vehicles, all by using real time object detection. If the project is adopted by the authorities, it will save countless accidents and also save the commuters money. The project may seem hard to adapt as it needs to be physically installed on many patrolling vehicles. However it will significantly reduce the time it takes for the road maintenance department to fill potholes as it takes several months and most of the times a real accident for citizens to file a report. The project is back with strong and proven technologies and with a vast variety of future plans, the project has a very strong foundation. The project leaves a huge foreground for further modifications or improvements and since we have more time to work on this, we assure you it will keep on getting better with time.

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