Wildfire Detection Using End-to-End Object Detection with Transformers

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Outline

Introduction

- Climate change is increasing the frequency and severity of wildfires.
- Traditional detection methods are slow and often inaccurate.
- Early detection is crucial for mitigating wildfire damage.
- **Objective**: Employ state-of-the-art computer vision techniques, specifically the DEtection TRansformer (DETR), to improve wildfire monitoring systems.

Background

- **DETR**: A transformer-based deep learning model for object detection.
- Utilizes self-attention mechanisms to recognize patterns across larger contexts.
- Underutilized in environmental monitoring applications.
- Our research applies DETR to the task of wildfire detection.

Data Components

- Dataset of 6,249 high-resolution images from RoboFlow.
- Images depict various wildfire scenarios with bounding boxes around fires.
- Landscapes vary in lighting, forest type, fire number, and fire size.
- Aimed to ensure model robustness across different wildfire contexts.

Data Preprocessing

1. **Dataset Download and Organization**
   - Downloaded from RoboFlow and organized into directories.
   - Annotations formatted in COCO JSON standard.
2. **Dataset Splitting**
   - 90% of images for training.
   - 10% of images for testing.
3. **Image Standardization and Resizing**
   - All images resized to 512 x 512 pixels.
4. **Bounding Box Normalization**
   - Coordinates normalized to a range between 0 and 1.
   - Ensures compatibility across varying image sizes.

Example Annotation Entry


```json
{
  "images": [
    {
      "id": 5631,
      "license": 1,
      "file_name": "82_869_927_...jpg",
      "height": 512,
      "width": 512,
      "date_captured": "2024-01-06T19:08:39+00:00"
    }
  ]
}
```

Model Architecture

- Utilized the DETR architecture with a ResNet-50 backbone.
- Leveraged pre-trained `facebook/detr-resnet-50` weights.
- Employed transfer learning to accelerate training and enhance performance.

Training Procedure

1. **Data Preparation**
   - Custom data loaders with `collate_fn` function.
   - Handled variable-sized ground truth data.
2. **Model Configuration**
   - Trained on a CUDA-enabled GPU.
3. **Training Loop**
   - Forward pass, loss calculation, backpropagation.
   - Optimizer: AdamW.
   - Loss tracking at regular intervals.
4. **Model Saving**
   - Checkpoints saved after each epoch.

Hyperparameter Tuning

- **Batch Size**: 10
- **Epochs**: 15
- **Training Size**: 90%
- Optimal configuration after experimenting with different combinations.

Evaluation Metrics

- **Mean Intersection over Union (mIoU)**
  - Measures overlap between predicted and ground truth bounding boxes.
- **Precision**
  - Proportion of correct wildfire detections.
- **Recall**
  - Proportion of actual wildfires correctly detected.

- Implemented parallel processing for efficiency.

Visualization

- Used `matplotlib` for plotting results.
- Displayed mIoU, Precision, and Recall versus detection threshold.
- Provided insights into optimal threshold settings.

`metrics_vs_threshold.png`

Model Performance

- **Training Loss**
  - Steady decrease from 5.5 to 0.32 over epochs.
- **Validation Loss**
  - Decreased from 0.98 to 0.42.
  - Minor fluctuations but overall positive trend.
- Indicates successful learning and good generalization.

Performance Metrics

Hyperparameters	Precision	Recall	mIoU
Batch size: 7, Epochs: 10	0.85	0.88	0.83
Batch size: 7, Epochs: 15	0.87	0.86	0.84
Batch size: 10, Epochs: 10	0.83	0.85	0.82
Batch size: 10, Epochs: 15	**0.86**	**0.87**	**0.83**

Table: Performance Metrics for Different Hyperparameters

Visualization of Results

metrics_vs_threshold.png

Reasons for Errors

- **Heavy Smoke**
  - Obscures key features needed to identify a wildfire.
- **Similar Colors**
  - Orange-leafed trees may be mistaken for fire due to color similarity.
- **Environmental Variability**
  - Diverse conditions make consistent detection challenging.

Conclusion

- Successfully demonstrated the potential of using DETR for wildfire detection.
- Model accurately identified fires across various environmental conditions.
- Both training and validation losses showed steady decreases.
- DETR could be integrated into real-world wildfire detection systems.
- **Future Work**:
  - Fine-tuning hyperparameters.
  - Addressing issues like smoke interference.
  - Optimizing the model for real-time deployment.

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References

- Carion, N., et al. (2020). End-to-End Object Detection with Transformers. *European Conference on Computer Vision*.
- RoboFlow Dataset. Available at: `https://roboflow.com/`

Thank You!