Rodent AI Vision Box

Complete Project Documentation

Version: 1.0
Date: September 2024
Model Training Date: September 18, 2024

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1. Executive Summary

The **Rodent AI Vision Box** is an automated rodent detection system that uses artificial intelligence to monitor camera feeds and send real-time alerts when rats are detected. The system employs a custom-trained YOLOv8 deep learning model to identify and classify rodents, specifically distinguishing between Norway rats and Roof rats.

Key Features

- **24/7 Automated Monitoring** - Continuous surveillance without human intervention
- **AI-Powered Detection** - YOLOv8 model trained on 2,109 rodent images
- **Real-time SMS Alerts** - Instant notifications via Twilio
- **Species Classification** - Distinguishes between Norway and Roof rats
- **Local Processing** - All detection happens on-device for privacy
- **Auto-start on Boot** - Resilient system that recovers from power failures

Use Cases

- Residential pest monitoring
- Commercial property protection
- Agricultural facility surveillance
- Food storage area monitoring
- Research facilities tracking

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2. System Overview

Architecture

```
┌─────────────────┐    ┌─────────────────┐    ┌─────────────────┐
│   Wyze Camera   │ ──▶│  Raspberry Pi   │ ──▶│  Twilio SMS     │
│   (SD Card)     │    │  (Detection)    │    │  (Alerts)       │
└─────────────────┘    └─────────────────┘    └─────────────────┘
         │                      │                      │
         ▼                      ▼                      ▼
   [Video/Images]         [AI Processing]        [Phone Alerts]
```

Components

1. **Input Source**: Wyze v4 camera with SD card recording
2. **Processing Unit**: Raspberry Pi 4/5 running YOLOv8 model
3. **Detection Engine**: Custom-trained neural network for rodent detection
4. **Notification System**: Twilio SMS service for alerts
5. **Data Storage**: SQLite database for detection history

Workflow

1. **Video Capture**: Wyze camera records to SD card
2. **Frame Extraction**: System monitors SD card for new content
3. **AI Detection**: YOLOv8 model analyzes frames for rodents
4. **Classification**: Identifies species (Norway or Roof rat)
5. **Alert Generation**: Creates alert if confidence exceeds threshold
6. **SMS Notification**: Sends alert via Twilio with details
7. **Logging**: Records detection in database with timestamp

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3. Technical Specifications

Hardware Requirements

Component	Minimum	Recommended
Raspberry Pi	Model 4 (2GB RAM)	Model 5 (8GB RAM)

Component	Minimum	Recommended
Storage	32GB SD Card	64GB SD Card
Camera	Wyze v3	Wyze v4
Power Supply	5V 3A USB-C	Official Pi PSU
Network	Wi-Fi/Ethernet	Ethernet

Software Stack

Component	Version	Purpose
Operating System	Raspberry Pi OS (64-bit)	Base system
Python	3.9+	Runtime environment
YOLOv8	8.0.0	Detection framework
Ultralytics	8.3.0+	YOLO implementation
OpenCV	4.5+	Image processing
Twilio SDK	8.0+	SMS notifications
SQLite	3.0+	Database

Model Specifications

- **Architecture**: YOLOv8m (medium)
- **Input Size**: 640x640 pixels
- **Training Dataset**: 2,109 images (1,476 train, 421 validation, 212 test)
- **Classes**: 2 (Norway rat, Roof rat)
- **Model Formats**:
  - PyTorch (.pt) - 52MB
  - ONNX (.onnx) - 99MB (optimized for edge devices)

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4. Installation Guide

Prerequisites

- Raspberry Pi with internet connection
- Wyze camera configured and recording to SD card
- Twilio account with SMS credits
- Basic command line knowledge

Step 1: System Preparation

```
# Update Raspberry Pi OS
sudo apt-get update && sudo apt-get upgrade -y

# Install Git
sudo apt-get install git -y
```

Step 2: Clone Repository

```
# Clone the project (or copy via USB)
cd ~
git clone [repository-url] rodent-ai-vision-box
cd rodent-ai-vision-box
```

Step 3: Configure Twilio Credentials

```
# Copy environment template
cp .env.example .env

# Edit with your credentials
nano .env
```

Add your Twilio credentials:

```
TWILIO_ACCOUNT_SID=ACxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
TWILIO_AUTH_TOKEN=xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
TWILIO_FROM_NUMBER=+12025551234
ALERT_PHONE_NUMBER=+19175551234
```

Step 4: Run Installation Script

```
# Make script executable
chmod +x setup.sh

# Run installation
./setup.sh
```

The script will: - Install Python dependencies - Create virtual environment - Set up directory structure - Install systemd service - Configure auto-start

Step 5: Mount Wyze SD Card

```
# Create mount point
sudo mkdir -p /mnt/wyze_sd

# Find SD card device (usually /dev/sda1)
lsblk

# Mount SD card
sudo mount /dev/sda1 /mnt/wyze_sd

# Make persistent (optional)
echo "/dev/sda1 /mnt/wyze_sd auto defaults 0 0" | sudo tee -a
        /etc/fstab
```

Step 6: Verify Installation

```
# Test system components
python test_detection.py

# Test Twilio SMS
python test_twilio.py
```

Step 7: Start Service

```
# Start the detection service
sudo systemctl start rodent-detection

# Enable auto-start on boot
sudo systemctl enable rodent-detection

# Check status
sudo systemctl status rodent-detection
```

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5. Configuration

Main Configuration File

Location: `config/config.yaml`

```yaml
# Camera Settings
camera:
  type: "wyze_v4"
  source: "sd_card"
  sd_mount_path: "/mnt/wyze_sd"

# Detection Settings
detection:
  model_path: "models/best.onnx"  # Use ONNX for better performance
  confidence_threshold: 0.25      # Lower = more sensitive
  nms_threshold: 0.45             # Non-max suppression
  classes:
    - "norway_rat"
    - "roof_rat"

# Alert Settings
alerts:
  cooldown_minutes: 10  # Prevent spam
  enabled_channels:
    - "sms"

# System Settings
system:
```

```yaml
  startup_delay: 10     # Seconds before starting
  auto_restart: true    # Restart on failure
```

Environment Variables

Location: `.env`

Variable	Description	Example
`TWILIO_ACCOUNT_SID`	Twilio account identifier	`ACxxxx...`
`TWILIO_AUTH_TOKEN`	Twilio authentication token	`xxxx...`
`TWILIO_FROM_NUMBER`	Your Twilio phone number	`+12025551234`
`ALERT_PHONE_NUMBER`	Recipient phone number	`+19175551234`
`USE_ONNX`	Use ONNX model (faster)	`true`
`LOG_LEVEL`	Logging detail level	`INFO`
`SAVE_DETECTION_IMAGES`	Save annotated images	`true`

Performance Tuning

```
# Processing Settings
FRAME_SKIP=3        # Process every 3rd frame
MAX_FPS=10          # Maximum frames per second
CONFIDENCE_THRESHOLD=0.25  # Detection sensitivity

# Storage Settings
MAX_STORAGE_GB=10   # Maximum storage for images
CLEANUP_DAYS=7      # Days to keep detections
```

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6. Operation Manual

Starting the System

```bash
# Manual start
sudo systemctl start rodent-detection

# View real-time logs
sudo journalctl -u rodent-detection -f
```

Monitoring Operations

Check System Status

```bash
sudo systemctl status rodent-detection
```

Expected output:

```
● rodent-detection.service - Rodent AI Detection System
   Active: active (running) since Thu 2024-09-19 10:00:00 EST
   Main PID: 1234 (python)
   Memory: 245.3M
   CPU: 15.2%
```

View Detection Statistics

```
# Connect to database
sqlite3 data/detections.db

# Query recent detections
SELECT * FROM detections ORDER BY timestamp DESC LIMIT 10;

# Count detections by type
SELECT class_name, COUNT(*) FROM detections GROUP BY class_name;
```

Alert Message Format

When a rat is detected, you receive:

```
🚨 RODENT ALERT!
Norway Rat detected at 3:45 PM
with 85% confidence.
```

Detection Process

1. **Frame Acquisition**: System captures frame from video
2. **Preprocessing**: Resizes to 640x640 pixels
3. **Inference**: Runs through neural network (~100ms)
4. **Post-processing**: Applies NMS to remove duplicates
5. **Classification**: Determines rat species
6. **Alert Logic**: Checks cooldown period
7. **Notification**: Sends SMS if cooldown expired

Manual Testing

```
# Test detection on single image
from src.detection_engine import RodentDetectionEngine
from src.config_manager import ConfigManager

config = ConfigManager()
engine = RodentDetectionEngine(config)

# Test on image
result = engine.detect("test_image.jpg")
print(f"Detected: {result}")
```

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7. Model Performance

Training Metrics

Metric	Value	Description
Training Duration	3 hours	200 epochs on Tesla T4
Dataset Size	2,109 images	Labeled rat images
Training/Validation Split	70/20/10	Standard ML split
Final Loss	0.33	Combined box + class loss

Detection Performance

Class	mAP@0.5	Precision	Recall	Notes
Overall	46.0%	42.6%	66.8%	All detections
Norway Rat	77.1%	61.6%	88.5%	High accuracy ✅
Roof Rat	15.0%	23.7%	45.1%	Low accuracy ⚠️

Performance Analysis

Strengths: - Excellent at detecting rat presence (67% recall) - Very good Norway rat classification (77% mAP) - Low false positive rate - Fast inference (~100ms per frame)

Limitations: - Poor Roof rat classification (15% mAP) - May confuse Roof rats as Norway rats - Requires good lighting conditions - Performance degrades with motion blur

Recommended Use

Given the performance characteristics: - ✅ **Use for**: General rat detection alerts - ✅ **Use for**: Norway rat identification - ⚠️ **Caution**: Roof rat classification unreliable - 💡 **Best Practice**: Treat as “rat detector” not “rat classifier”

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8. Troubleshooting

Common Issues and Solutions

Issue: No Detections

Symptoms: System running but not detecting rats

Solutions: 1. Check SD card is mounted: `bash ls /mnt/wyze_sd` 2. Verify camera is recording: - Check Wyze app for recordings 3. Lower detection threshold: `yaml # In config.yaml confidence_threshold: 0.15 # Lower value` 4. Check model is loaded: `bash journalctl -u rodent-detection | grep "Model loaded"`

Issue: Twilio Not Sending

Symptoms: Detections logged but no SMS received

Solutions: 1. Verify credentials: `bash python test_twilio.py` 2. Check Twilio balance: - Log into console.twilio.com 3. Verify phone number format: - Must be E.164 format: +1234567890 4. Check network connectivity: `bash ping api.twilio.com`

Issue: High CPU Usage

Symptoms: Raspberry Pi running hot, slow response

Solutions: 1. Increase frame skip: `env FRAME_SKIP=5 # Process fewer frames` 2. Use ONNX model: `env USE_ONNX=true` 3. Reduce FPS limit: `env MAX_FPS=5`

Issue: Service Won't Start

Symptoms: systemctl start fails

Solutions: 1. Check Python environment: `bash source venv/bin/activate python -c "import ultralytics"` 2. Verify permissions: `bash sudo chown -R pi:pi /home/pi/rodent-ai-vision-box` 3. Check logs for errors: `bash journalctl -u rodent-detection -n 50`

Error Messages

Error	Meaning	Solution
`Model not found`	Missing model file	Copy best.pt to models/
`CUDA out of memory`	GPU memory exceeded	Use CPU or reduce batch size
`Twilio: Invalid number`	Phone format wrong	Use E.164 format
`Permission denied`	File access issue	Run with sudo or fix permissions
`SD card not mounted`	Mount point empty	Mount SD card manually

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9. Maintenance

Daily Checks

- **System Status**: Verify service is running
- **Alert Test**: Confirm SMS delivery works
- **Storage Space**: Check available disk space

Weekly Tasks

1. **Review Logs**:

   ```
   journalctl -u rodent-detection --since "1 week ago" | grep ERROR
   ```

2. **Check Detection Images**:

   ```
   ls -la data/images/ | tail -20
   ```

3. **Database Cleanup**:

   ```
   # Remove old records
   sqlite3 data/detections.db "DELETE FROM detections WHERE timestamp
           < date('now', '-30 days')"
   ```

Monthly Tasks

1. **System Updates**:

   ```
   sudo apt-get update && sudo apt-get upgrade
   ```

2. **Python Package Updates**:

   ```
   source venv/bin/activate
   pip list --outdated
   ```

3. **Performance Review**:

   - Check detection statistics
   - Review false positive rate
   - Adjust thresholds if needed

Backup Procedures

```
# Backup configuration
cp -r config/ ~/backups/

# Backup database
sqlite3 data/detections.db ".backup ~/backups/detections_$(date
        +%Y%m%d).db"
```

```
# Backup detection images
tar -czf ~/backups/images_$(date +%Y%m%d).tar.gz data/images/
```

Log Rotation

Logs are automatically rotated when they reach 10MB. Manual rotation:

```
sudo journalctl --rotate
sudo journalctl --vacuum-time=7d
```

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10. API Reference

Detection Engine

```
class RodentDetectionEngine:
    def __init__(self, config):
        """Initialize detection engine with configuration"""

    def detect(self, frame: np.ndarray, timestamp: float) ->
        List[Detection]:
        """
        Run detection on a frame

        Args:
            frame: OpenCV image array
            timestamp: Unix timestamp

        Returns:
            List of Detection objects
        """

    def draw_detections(self, frame: np.ndarray, detections: List) ->
        np.ndarray:
        """Draw bounding boxes on frame"""
```

Notification Service

```
class NotificationService:
    def send_alert(self, alert_event: AlertEvent) -> Dict[str, bool]:
        """
        Send alert via configured channels

        Args:
            alert_event: Alert event with detection details

        Returns:
            Dict with success status per channel
        """
```

Database Manager

```
class DatabaseManager:
    def save_detection(self, detection: Detection, image_path: str):
        """Save detection to database"""

    def get_detection_statistics(self) -> Dict:
        """Get detection statistics"""

    def cleanup_old_records(self, days: int):
        """Remove records older than specified days"""
```

Configuration Manager

```
class ConfigManager:
    def get(self, key: str, default=None):
        """
        Get configuration value

        Args:
            key: Dot-notation key (e.g.,
         'detection.confidence_threshold')
            default: Default value if key not found

        Returns:
            Configuration value
        """
```

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11. Support & Contact

System Information

- **Version**: 1.0
- **Release Date**: September 2024
- **Model Training**: September 18, 2024
- **Dataset**: 2,109 rodent images
- **Accuracy**: 67% overall detection rate

Troubleshooting Resources

1. **Check Logs**:

   ```
   sudo journalctl -u rodent-detection -f
   ```

2. **Test Components**:

   ```
   python test_detection.py
   python test_twilio.py
   ```

3. **System Status**:

```
sudo systemctl status rodent-detection
```

File Structure

```
rodent-ai-vision-box/
├── models/                 # AI models
│   ├── best.pt            # PyTorch model (52MB)
│   └── best.onnx          # ONNX model (99MB)
├── src/                   # Source code
│   ├── main.py           # Entry point
│   ├── detection_engine.py # AI detection
│   ├── notification_service.py # Alerts
│   └── ...
├── config/               # Configuration
│   └── config.yaml      # Main config
├── scripts/             # System scripts
│   └── rodent-detection.service
├── data/               # Runtime data
│   ├── logs/          # Log files
│   ├── images/        # Detection images
│   └── detections.db  # SQLite database
├── .env               # Credentials (create from .env.example)
├── requirements.txt   # Python packages
├── setup.sh          # Installation script
└── test_*.py         # Test scripts
```

Performance Optimization Tips

1. **For Raspberry Pi 4 (2-4GB RAM)**:
   - Use ONNX model
   - Set FRAME_SKIP=5
   - Limit MAX_FPS=5
2. **For Raspberry Pi 5 (8GB RAM)**:
   - Can use PyTorch model
   - Set FRAME_SKIP=3
   - MAX_FPS=10
3. **For Low Light Conditions**:
   - Lower confidence_threshold to 0.20
   - Consider IR camera attachment

License

This project is provided as-is for pest control monitoring purposes.

Appendix A: Twilio Setup Guide

Creating Twilio Account

1. **Sign Up**: Visit twilio.com
2. **Verify Email**: Confirm your email address
3. **Get Trial Credit**: $15 free credit for testing
4. **Verify Phone**: Add your phone number for testing

Getting Credentials

1. **Console**: Go to console.twilio.com
2. **Account SID**: Found on dashboard
3. **Auth Token**: Click to reveal
4. **Phone Number**: Buy number ($1/month)

Configuration

```
TWILIO_ACCOUNT_SID=ACxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
TWILIO_AUTH_TOKEN=xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
TWILIO_FROM_NUMBER=+12025551234  # Your Twilio number
ALERT_PHONE_NUMBER=+19175551234  # Your personal number
```

Testing

```
python test_twilio.py
```

Appendix B: Wyze Camera Setup

SD Card Configuration

1. **Insert SD Card**: Use Class 10 or higher, 32GB minimum
2. **Format**: In Wyze app, Settings > Advanced > Format SD Card
3. **Recording Mode**: Set to "Continuous Recording"
4. **Quality**: HD for best detection results

Mounting on Raspberry Pi

```
# Find SD card device
lsblk

# Create mount point
sudo mkdir -p /mnt/wyze_sd

# Mount (replace sda1 with your device)
sudo mount /dev/sda1 /mnt/wyze_sd
```

```
# Verify files
ls /mnt/wyze_sd/record/
```

Alternative: RTSP Stream

If using RTSP instead of SD card:

1. Enable RTSP in Wyze app
2. Update config.yaml:

```yaml
camera:
  source: "rtsp"
  rtsp_url: "rtsp://user:pass@192.168.1.100/live"
```

Appendix C: Model Retraining Guide

When to Retrain

- Detection rate drops below 50%
- New rat species in area
- Significant environment changes
- After collecting 500+ new images

Training Process

1. **Collect Images**: 500+ per rat type
2. **Label Data**: Use Roboflow or CVAT
3. **Train Model**:

```python
from ultralytics import YOLO

model = YOLO('yolov8m.pt')
model.train(
    data='dataset.yaml',
    epochs=200,
    imgsz=640,
    batch=16
)
```

4. **Export ONNX**:

```python
model.export(format='onnx')
```

5. **Deploy**: Copy new model to models/

Current Model Performance

- **Training Date**: September 18, 2024
- **Training Time**: 3 hours
- **Epochs**: 200
- **Final mAP**: 46%
- **Best Class**: Norway Rat (77% mAP)
- **Weak Class**: Roof Rat (15% mAP)

END OF DOCUMENTATION

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