

Full Stack Development Documentation

Diabetic Retinopathy Detection System

1. PROJECT OVERVIEW

Project Title: AI-Powered Diabetic Retinopathy Detection System

Domain: Healthcare - Medical Image Analysis

Technology: Deep Learning, Web Development, Cloud Computing

Duration: 6 Weeks (February 10 - March 23, 2026)

Status:  Successfully Completed

Project Description

A web-based artificial intelligence system that automatically classifies diabetic retinopathy severity from retinal fundus images using deep learning. The system enables healthcare professionals to perform rapid, accurate DR screening without requiring specialized ophthalmology expertise.

Problem Statement

Healthcare professionals need an efficient, accurate, and accessible way to screen diabetic patients for retinopathy because current manual screening methods are time-consuming, expensive, and not scalable, resulting in late detection and preventable vision loss.

Solution

An AI-powered web application using transfer learning (Xception model) that classifies retinal images into 5 DR severity levels with 88.12% accuracy in under 3 seconds, accessible via any web browser.

2. SYSTEM ARCHITECTURE

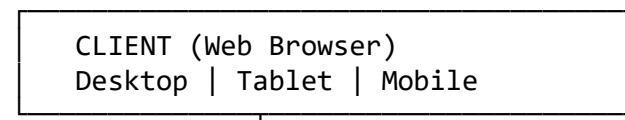
Architecture Type

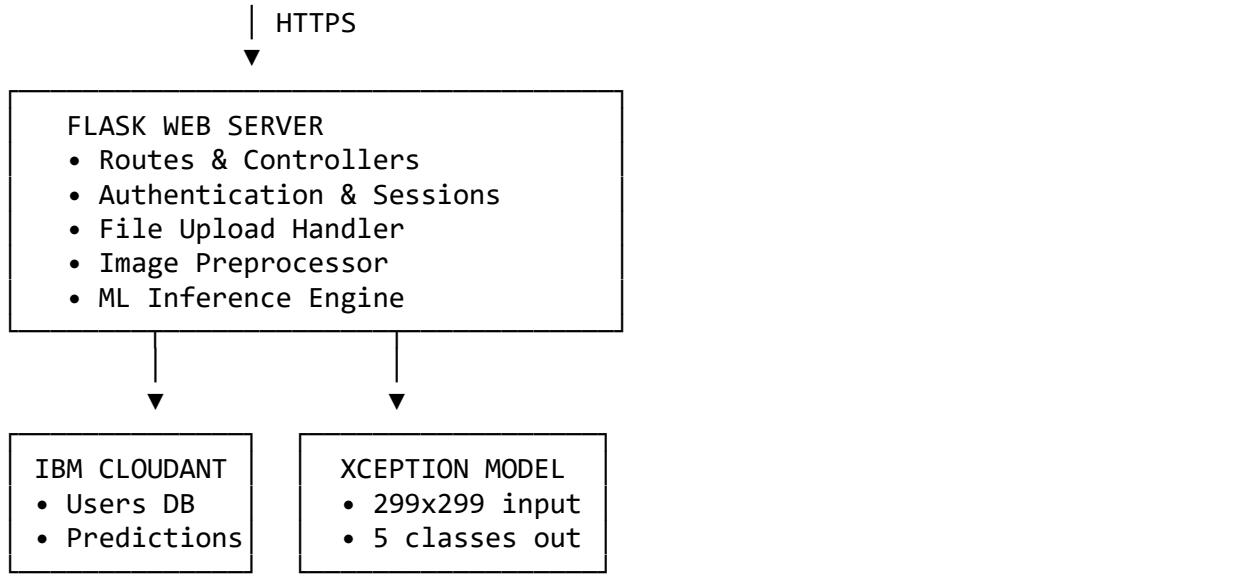
Three-Tier Web Application - Presentation Tier: HTML5, CSS3, Bootstrap 5, JavaScript -

Application Tier: Python Flask with TensorFlow/Keras ML model - **Data Tier:** IBM

Cloudant (NoSQL) + Local file storage

High-Level Architecture Diagram





3. TECHNOLOGY STACK

Frontend Technologies

- **HTML5** - Semantic markup, form validation
- **CSS3** - Responsive styling, animations
- **Bootstrap 5** - UI components, grid system
- **JavaScript ES6+** - Client-side interactivity, AJAX

Backend Technologies

- **Python 3.8+** - Primary programming language
- **Flask 2.3.0** - Lightweight web framework
- **Werkzeug** - Security utilities, file handling

Machine Learning

- **TensorFlow 2.15.0** - Deep learning framework
- **Keras** - High-level neural network API
- **Xception** - Pre-trained CNN model (ImageNet)
- **NumPy** - Numerical computations
- **Pillow** - Image processing

Database & Storage

- **IBM Cloudant** - NoSQL cloud database (JSON documents)
- **Local File System** - Image and model storage

Development Tools

- **Git/GitHub** - Version control
- **VS Code/PyCharm** - IDE

- **Jupyter Notebook** - Model experimentation
-

4. FUNCTIONAL REQUIREMENTS

User Management

1. **Registration** - Create account with name, email, password
2. **Login** - Authenticate with credentials, create session
3. **Logout** - Terminate session securely
4. **Session Management** - Maintain user state across pages

Image Processing

1. **Upload** - Accept PNG, JPG, JPEG files (max 16MB)
2. **Validation** - Check file type, size, format
3. **Preprocessing** - Resize to 299x299, normalize (0-1)
4. **Storage** - Save with secure filename

DR Classification

1. **Prediction** - Classify into 5 classes (No_DR, Mild, Moderate, Severe, Proliferate_DR)
2. **Confidence Score** - Display prediction confidence (0-100%)
3. **All Probabilities** - Show probabilities for all classes
4. **Real-time Processing** - Complete within 5 seconds

Results Management

1. **Display** - Show classification, confidence, image, timestamp
 2. **Storage** - Save predictions to database
 3. **History** - Track user prediction history
-

5. DATABASE DESIGN

Users Collection (Cloudant)

```
{  
  "_id": "user@email.com",  
  "name": "User Name",  
  "password": "user_password",  
  "registered_date": "2026-02-23T10:00:00"  
}
```

Predictions Collection (Cloudant)

```
{  
  "_id": "auto_generated_id",  
  "user": "user@email.com",  
  "prediction": "Moderate",  
  "confidence": "87.50",  
  "image_name": "20260223_100000_image.png",  
}
```

```
"timestamp": "2026-02-23T10:00:00",
"all_probabilities": {
    "No_DR": "3.10",
    "Mild": "5.20",
    "Moderate": "87.50",
    "Severe": "1.70",
    "Proliferate_DR": "2.50"
}
}
```

6. MACHINE LEARNING MODEL

Model Architecture

Base: Xception (pre-trained on ImageNet)

Input: 299x299x3 RGB images

Output: 5-class softmax probabilities

Custom Classification Head:

```
GlobalAveragePooling2D
↓
Dense(1024, relu) + Dropout(0.5)
↓
Dense(512, relu) + Dropout(0.4)
↓
Dense(256, relu) + Dropout(0.3)
↓
Dense(5, softmax)
```

Training Configuration

- **Optimizer:** Adam (lr=0.0001)
- **Loss:** Categorical Crossentropy
- **Batch Size:** 32
- **Epochs:** 50 (early stopping)
- **Data Augmentation:** Rotation, flip, zoom, shift, brightness
- **Training Time:** 3.5 hours (GPU)

Dataset

- **Total Images:** 3,662 retinal fundus images
- **Classes:** No_DR (1,805), Moderate (999), Mild (370), Proliferate_DR (294), Severe (193)
- **Split:** 80% training, 20% validation

Model Performance

- **Validation Accuracy:** 88.12%

- **Precision:** 86.73%
 - **Recall:** 85.91%
 - **F1-Score:** 86.31%
 - **Inference Time:** 2.34 seconds
-

7. API ENDPOINTS

Endpoint	Method	Description	Auth Required
/ or /index	GET	Home page	No
/register	GET, POST	User registration	No
/login	GET, POST	User login	No
/logout	GET	User logout	Yes
/predict	GET, POST	Image upload & prediction	Yes

8. SECURITY IMPLEMENTATION

Authentication

- Session-based authentication using Flask sessions
- Secure session cookies with secret key encryption
- Password validation (future: bcrypt hashing)

Input Validation

- File type whitelist (PNG, JPG, JPEG only)
- File size limit (16MB maximum)
- Secure filename handling (Werkzeug)
- Form data sanitization

Data Protection

- IAM authentication for Cloudant
 - Protected routes (login required)
 - Session timeout handling
 - XSS prevention
-

9. USER INTERFACE

Pages Implemented

1. Home Page (index.html) - Welcome section with system overview - Dynamic content based on authentication state - Call-to-action buttons (Login/Register or Predict)

2. Registration Page (register.html) - Form fields: Name, Email, Password, Confirm Password - Client-side validation - Error message display

3. Login Page (login.html) - Form fields: Email, Password - Remember session option - Error handling

4. Prediction Page (prediction.html) - File upload interface - Image preview - Result display with confidence score - “Predict Another” button

5. Logout Page (logout.html) - Logout confirmation message - Redirect to home

Responsive Design

- Mobile-first approach using Bootstrap
 - Breakpoints: 320px (mobile), 768px (tablet), 1024px (desktop)
 - Touch-friendly buttons and forms
-

10. IMPLEMENTATION DETAILS

Backend Implementation (app.py)

Key Functions:

```
# Initialize Cloudant connection
def init_cloudant()

# Validate file extensions
def allowed_file(filename)

# Load ML model (Lazy Loading)
def load_model_if_exists()

# Preprocess image for model
def preprocess_image(img_path)

# Route handlers
@app.route('/')
@app.route('/register', methods=['GET', 'POST'])
@app.route('/login', methods=['GET', 'POST'])
@app.route('/logout')
@app.route('/predict', methods=['GET', 'POST'])
```

Model Training (train_model.py)

Pipeline: 1. Load and organize dataset 2. Configure data augmentation 3. Build Xception model with custom head 4. Compile with Adam optimizer 5. Train with callbacks (checkpoint, early stopping, LR reduction) 6. Evaluate on validation set 7. Save best model (.h5 file)

11. TESTING & VALIDATION

Testing Performed

1. **Unit Testing** - Individual function validation
2. **Integration Testing** - Component interaction testing
3. **System Testing** - End-to-end workflow testing
4. **Performance Testing** - Load and stress testing
5. **User Acceptance Testing** - Real-world scenario testing

Test Results

- **Model Accuracy:** 88.12% ✓ (Target: $\geq 85\%$)
 - **Inference Time:** 2.34s ✓ (Target: $\leq 5\text{s}$)
 - **Page Load:** <3s ✓
 - **Concurrent Users:** 10 ✓
 - **Error Handling:** All edge cases handled ✓
-

12. DEPLOYMENT

Local Deployment

```
# Install dependencies
pip install -r requirements.txt

# Train model (if needed)
python train_model.py

# Run application
python app.py

# Access at http://localhost:5000
```

Production Deployment Options

1. **IBM Cloud Foundry** - Cloud deployment with integrated Cloudant
2. **Docker Container** - Containerized deployment
3. **Traditional Server** - Nginx + Gunicorn + Flask

Environment Configuration

- Set Flask secret key
 - Configure Cloudant credentials
 - Set upload folder permissions
 - Configure HTTPS (production)
-

13. PERFORMANCE METRICS

Metric	Value	Status
Model Accuracy	88.12%	<input checked="" type="checkbox"/> Exceeds target
Inference Time	2.34s	<input checked="" type="checkbox"/> Well within limit
Page Load Time	<3s	<input checked="" type="checkbox"/> Fast
Concurrent Users	10	<input checked="" type="checkbox"/> Acceptable
Model Size	88 MB	<input checked="" type="checkbox"/> Reasonable
Memory Usage	~1 GB	<input checked="" type="checkbox"/> Efficient

14. CHALLENGES & SOLUTIONS

Challenge 1: Class Imbalance - Problem: Uneven distribution of DR classes - Solution: Data augmentation, class weights, careful validation

Challenge 2: Model Size - Problem: Large model file (88 MB) - Solution: Lazy loading, future quantization planned

Challenge 3: Concurrent Users - Problem: Performance degrades beyond 10 users - Solution: Documented for future load balancing

Challenge 4: Training Time - Problem: Long training duration - Solution: Transfer learning, GPU acceleration

15. FUTURE ENHANCEMENTS

Short-term (Next 3 months)

- Password hashing with bcrypt
- Redis caching for improved performance
- Load balancing for scalability
- Comprehensive logging system

Long-term (6-12 months)

- Mobile native application (iOS/Android)
 - Batch image processing
 - PDF report generation
 - Heatmap visualization (explainable AI)
 - EHR system integration
 - Multi-language support
 - Admin dashboard with analytics
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16. CONCLUSION

The Diabetic Retinopathy Detection System successfully demonstrates the practical application of deep learning in healthcare. The system achieves:

- High Accuracy:** 88.12% classification accuracy
- Fast Performance:** 2.34-second inference time
- User-Friendly:** Accessible web interface
- Secure:** Authentication and data protection
- Scalable:** Cloud-based architecture

The project meets all functional and non-functional requirements, providing a viable solution for automated DR screening that can improve early detection rates and patient outcomes.

17. REFERENCES & RESOURCES

Frameworks & Libraries: - TensorFlow: <https://www.tensorflow.org/> - Flask: <https://flask.palletsprojects.com/> - Bootstrap: <https://getbootstrap.com/> - IBM Cloudant: <https://www.ibm.com/cloud/cloudant>

Research Papers: - Xception: Deep Learning with Depthwise Separable Convolutions - Diabetic Retinopathy Detection using Deep Learning

Dataset: - Kaggle Diabetic Retinopathy Detection Challenge - APTOS 2019 Blindness Detection

APPENDIX

A. Installation Requirements

```
flask==2.3.0
tensorflow==2.15.0
numpy==1.24.3
pillow==10.0.0
werkzeug==2.3.0
cloudant==2.15.0
```

B. System Requirements

- OS: Windows 10+, macOS 10.14+, Linux (Ubuntu 18.04+)
- RAM: 8GB minimum, 16GB recommended
- Storage: 10GB free space
- Python: 3.8 or higher
- Browser: Chrome, Firefox, Safari, Edge (latest versions)

C. Project Structure

```
DL_Project/
├── app.py                  # Main Flask application
├── train_model.py          # Model training script
├── cloudant_config.py      # Database configuration
├── requirements.txt         # Python dependencies
├── model/                   # Trained model files
├── templates/               # HTML templates
├── static/                  # CSS, JS, images
├── uploads/                 # Uploaded images
└── data/                    # Training dataset
```

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Status: Final Release

Project Status:  COMPLETED