



Updated Directory Structure with Enhanced Components

Server-Side Directory (Enhanced)

```
zkp_biometric_voting_server/
├── README.md
├── requirements.txt
├── app.py                                # Main Flask application (enhanced)
├── config/
│   ├── server_config.yaml
│   ├── database_config.yaml
│   └── security_config.yaml          # NEW: Enhanced security parameters
├── core/                                # Enhanced core components
│   ├── __init__.py
│   ├── enhanced_pqc_crypto.py        # NEW: Lattice-based PQC (Kyber/Dilithium)
│   ├── enhanced_zkp_module.py        # NEW: Advanced ZKP with range proofs
│   ├── enhanced_biometric_auth.py    # NEW: Multi-modal + template protection
│   ├── blockchain_voting.py          # Original blockchain (maintained)
│   ├── voting_system.py              # Original system (maintained)
│   └── legacy/                        # NEW: Original implementations
│       ├── pqc_crypto.py             # Original simplified PQC
│       ├── zkp_module.py             # Original ZKP
│       └── biometric_auth.py         # Original biometric
├── server/                              # Enhanced server components
│   ├── __init__.py
│   ├── enhanced_server_real_data.py  # NEW: Advanced real data handler
│   ├── server_auth.py                # Enhanced authentication server
│   ├── server_homomorphic.py         # Homomorphic processing
│   ├── enhanced_blockchain.py        # Enhanced blockchain with HE
│   ├── security_manager.py           # NEW: Security policy manager
│   └── performance_monitor.py        # NEW: System performance monitoring
├── research/                            # NEW: Research-specific components
│   ├── __init__.py
│   ├── crypto_benchmarks.py          # NEW: Cryptographic benchmarking
│   ├── biometric_analysis.py         # NEW: Advanced biometric analysis
│   ├── zkp_verification_tests.py     # NEW: ZKP protocol testing
│   └── security_evaluation.py         # NEW: Security assessment tools
├── testing/                             # Enhanced testing framework
│   └── __init__.py
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├── dataset_handler.py           # Enhanced SOCOfing handler
├── advanced_test_suite.py       # NEW: Comprehensive test suite
├── crypto_unit_tests.py        # NEW: Cryptographic unit tests
├── biometric_security_tests.py  # NEW: Biometric security evaluation
├── integration_tests.py        # NEW: Full system integration tests
├── dataset/                    # Enhanced dataset structure
│   ├── Real/                  # Real fingerprints (server-side)
│   │   ├── subject_001/
│   │   ├── subject_002/
│   │   └── ...
│   ├── processed/             # NEW: Processed feature data
│   │   ├── fingerprint_features/
│   │   ├── iris_features/
│   │   └── protected_templates/
│   ├── metadata/
│   │   ├── socofing_metadata.db
│   │   ├── feature_statistics.json  # NEW: Feature analysis
│   │   └── security_metrics.json    # NEW: Security evaluation metrics
│   ├── benchmarks/           # NEW: Benchmark datasets
│   │   ├── attack_samples/
│   │   └── synthetic_variants/
├── storage/                   # Enhanced storage
│   ├── blockchain_data/
│   │   ├── blocks/
│   │   ├── transactions/
│   │   └── integrity_logs/        # NEW: Blockchain integrity logs
│   ├── voter_registry/
│   │   ├── registered_voters.db
│   │   ├── protected_templates.db  # NEW: Protected biometric templates
│   │   └── audit_trail.db          # NEW: Complete audit trail
│   ├── crypto_keys/           # NEW: Cryptographic key storage
│   │   ├── pqc_keys/
│   │   ├── zkp_parameters/
│   │   └── system_certificates/
│   ├── logs/
│   │   ├── server.log
│   │   ├── security.log           # NEW: Security events
│   │   ├── performance.log        # NEW: Performance metrics
│   │   └── research.log           # NEW: Research experiment logs
│   ├── backups/               # NEW: System backups
│   │   ├── daily/
│   │   └── weekly/
├── scripts/
│   ├── setup_server.sh
│   ├── start_server.py
│   ├── setup_enhanced_system.sh   # NEW: Enhanced system setup
│   ├── crypto_key_generation.py   # NEW: Advanced key generation
│   ├── benchmark_runner.py         # NEW: Automated benchmarking
│   └── security_audit.py           # NEW: Security audit script

```

Client-Side Directory (Enhanced)

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zkp_biometric_voting_client/
├── README.md
├── requirements.txt
├── main.py # Enhanced main client application
├── config/
│   ├── client_config.yaml
│   ├── research_config.yaml # NEW: Research experiment settings
│   └── benchmark_config.yaml # NEW: Benchmarking configuration
├── core/ # Same enhanced core as server
│   ├── __init__.py
│   ├── enhanced_pqc_crypto.py # Lattice-based PQC
│   ├── enhanced_zkp_module.py # Advanced ZKP
│   ├── enhanced_biometric_auth.py # Multi-modal biometrics
│   ├── blockchain_voting.py
│   ├── voting_system.py
│   └── legacy/ # Original implementations
│       ├── pqc_crypto.py
│       ├── zkp_module.py
│       └── biometric_auth.py
├── client/ # Enhanced client components
│   ├── __init__.py
│   ├── enhanced_client_biometric.py # NEW: Advanced client biometric handler
│   ├── client_zkp.py # Enhanced ZKP client
│   ├── homomorphic_client.py # Homomorphic encryption client
│   ├── enhanced_client_test_data.py # NEW: Advanced test data handler
│   ├── enhanced_voting_system.py # Enhanced voting system
│   ├── complete_voting_flow.py # Complete voting workflow
│   ├── crypto_client.py # NEW: Advanced crypto client
│   └── research_client.py # NEW: Research experiment client
├── research/ # NEW: Client-side research tools
│   ├── __init__.py
│   ├── attack_simulation.py # NEW: Attack simulation framework
│   ├── privacy_analysis.py # NEW: Privacy analysis tools
│   ├── performance_profiler.py # NEW: Performance profiling
│   ├── comparative_analysis.py # NEW: Algorithm comparison
│   └── experiment_runner.py # NEW: Automated experiment runner
├── testing/ # Comprehensive testing framework
│   ├── __init__.py
│   ├── dataset_handler.py # Enhanced dataset handler
│   ├── advanced_test_voting_system.py # NEW: Advanced system tests
│   ├── crypto_correctness_tests.py # NEW: Cryptographic correctness
│   ├── biometric_robustness_tests.py # NEW: Biometric robustness testing
│   ├── zkp_soundness_tests.py # NEW: ZKP soundness verification
│   ├── security_analysis.py # Enhanced security analysis
│   ├── attack_resistance_tests.py # NEW: Attack resistance evaluation
│   └── comparative_benchmarks.py # NEW: Comparative benchmarking
├── dataset/ # Full SOCOFing dataset (client-side)
│   └── Real/ # Real fingerprints (limited subset)

```

- └─ Altered-Easy/ # Easy alterations
- └─ Altered-Medium/ # Medium alterations
- └─ Altered-Hard/ # Hard alterations
- └─ Synthetic/ # Synthetic fingerprints
- └─ processed/ # NEW: Processed features
 - └─ gabor_features/
 - └─ lbp_features/
 - └─ minutiae_features/
 - └─ texture_features/
- └─ attack_samples/ # NEW: Attack simulation data
 - └─ spoofing_attacks/
 - └─ presentation_attacks/
 - └─ synthetic_attacks/
- └─ metadata/
 - └─ socofing_metadata.db
 - └─ feature_analysis.json # NEW: Feature analysis results
 - └─ attack_vectors.json # NEW: Attack vector documentation
- └─ ground_truth/ # NEW: Ground truth for evaluation
 - └─ genuine_pairs.json
 - └─ impostor_pairs.json
 - └─ attack_labels.json
- └─ results/ # Enhanced results structure
 - └─ authentication_results/
 - └─ genuine_scores/
 - └─ impostor_scores/
 - └─ roc_curves/
 - └─ voting_results/
 - └─ transaction_logs/
 - └─ blockchain_analysis/
 - └─ privacy_metrics/
 - └─ performance_metrics/
 - └─ crypto_benchmarks/
 - └─ biometric_timings/
 - └─ system_throughput/
 - └─ security_analysis/ # NEW: Security evaluation results
 - └─ attack_success_rates/
 - └─ privacy_leakage/
 - └─ robustness_scores/
 - └─ research_experiments/ # NEW: Research experiment results
 - └─ algorithm_comparisons/
 - └─ parameter_studies/
 - └─ ablation_studies/
 - └─ reports/
 - └─ comprehensive_evaluation.html
 - └─ security_assessment.pdf
 - └─ performance_report.json
 - └─ research_findings.md # NEW: Research documentation
- └─ documentation/ # NEW: Enhanced documentation
 - └─ api_reference.md
 - └─ crypto_specifications.md # NEW: Cryptographic specifications
 - └─ biometric_protocols.md # NEW: Biometric protocol documentation
 - └─ security_model.md # NEW: Security model description
 - └─ research_methodology.md # NEW: Research methodology
 - └─ experiment_protocols.md # NEW: Experiment protocols

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└─ scripts/
    ├── setup_client.sh
    ├── run_tests.py
    ├── setup_enhanced_client.sh      # NEW: Enhanced client setup
    ├── run_experiments.py          # NEW: Automated experiment runner
    ├── generate_reports.py          # NEW: Report generation
    ├── benchmark_suite.py           # NEW: Comprehensive benchmarking
    └── data_analysis.py             # NEW: Data analysis utilities
```

Key Directory Structure Enhancements:

1. Enhanced Core Components

- **enhanced_* files:** Advanced implementations with lattice-based crypto, multi-modal biometrics, and improved ZKP
- **legacy/ folder:** Preserves original implementations for comparison
- **Research-oriented structure:** Dedicated research folders for experiments

2. Advanced Testing Framework

- **Comprehensive test suites:** Crypto correctness, biometric robustness, ZKP soundness
- **Attack simulation:** Framework for testing various attack scenarios
- **Benchmark infrastructure:** Automated performance and security benchmarking

3. Enhanced Data Management

- **Processed features:** Pre-computed features for faster experiments
- **Attack samples:** Dedicated storage for attack simulation data
- **Ground truth:** Properly labeled datasets for evaluation

4. Research Infrastructure

- **Experiment management:** Tools for running and managing research experiments
- **Comparative analysis:** Framework for comparing different algorithms
- **Performance profiling:** Detailed performance analysis tools

5. Security and Monitoring

- **Security audit tools:** Automated security assessment
- **Performance monitoring:** Real-time system performance tracking
- **Comprehensive logging:** Detailed logs for all system components

6. Documentation and Reports

- **API documentation:** Complete API reference
- **Research documentation:** Methodology and experimental protocols
- **Automated reporting:** Tools for generating comprehensive reports

This enhanced directory structure maintains compatibility with the original design while adding significant research capabilities and improved security features suitable for academic research and comprehensive security evaluation.