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## TradeWatch System Architecture Documentation

### Overview

TradeWatch is a comprehensive Global Trade Intelligence Platform that provides real-time monitoring, AI-powered analytics, and predictive insights for maritime trade operations.

### System Architecture

#### Frontend Layer (React/JavaScript)

- **React Dashboard:** Main application interface with real-time data visualization
- **Global Map Component:** Interactive Leaflet.js map showing vessels, ports, disruptions
- **Vessel Tracking:** Dedicated page for monitoring 5000+ maritime vessels
- **Disruption Timeline:** Real-time display of maritime incidents and forecasts
- **AI Projections Widget:** Machine learning predictions and analytics
- **Mobile Responsive Design:** Optimized for all device types

#### API Gateway (FastAPI/Python)

- **FastAPI Server:** High-performance API server on port 8001
- **CORS Middleware:** Cross-origin resource sharing for web clients
- **Rate Limiting:** API throttling and abuse prevention
- **Data Validation:** Input sanitization and error handling
- **Real-time Endpoints:** Live data streaming capabilities

## Data Processing Layer

### Real-time Data Fetcher

- **RSS Feed Parser:** Processes maritime news from 15+ sources
- **Maritime API Aggregator:** Integrates official trade and weather APIs
- **AIS Integration Service:** Vessel positioning and tracking data
- **Quality Filtering:** Confidence scoring and data validation

### Coordinate Validation System

- **Land Detection Engine:** Prevents vessel positioning over landmasses
- **Maritime Route Engine:** Realistic shipping lane positioning
- **Geospatial Validation:** Coordinate accuracy verification

### AI Prediction Service

- **TensorFlow Models:** Machine learning for trade predictions
- **Historical Data Analyzer:** Trend analysis and pattern recognition
- **Risk Assessment:** Automated threat and impact evaluation

### Database Layer (PostgreSQL)

- **Vessel Data Table:** 5000+ vessel records with real-time positions
- **Disruption Events Table:** 122+ maritime incidents and forecasts
- **Tariff Policies Table:** 500+ international trade policies
- **Port Information Table:** 200+ major global ports
- **AI Training Data Table:** Historical data for model training

### External Data Sources

#### Maritime Information

- **RSS Feeds:** gCaptain, Splash247, FreightWaves, Seatrade Maritime
- **Official APIs:** IMO, port authorities, shipping companies
- **Weather Services:** NOAA, Weather Channel marine forecasts

#### Trade Intelligence

- **Government APIs:** WTO, USTR, EU Commission trade data
- **Economic Indicators:** Baltic Dry Index, trade statistics
- **News Services:** BBC World, Reuters international coverage

### AI/ML Pipeline

1. **Data Ingestion:** Automated collection from multiple sources
2. **Feature Engineering:** Data transformation and preparation
3. **Model Training:** TensorFlow-based prediction models
4. **Prediction Generation:** Real-time forecasting and analytics
5. **Confidence Scoring:** Reliability assessment for predictions
6. **Risk Assessment:** Automated threat level evaluation

## Key Features

### Real-time Data Processing

- **122+ Live Disruptions:** Maritime incidents from authoritative sources
- **5000+ Vessel Tracking:** Real-time AIS data integration

- **500+ Trade Policies:** Current tariff and regulation monitoring
- **200+ Port Status:** Global port operations and congestion data

### AI-Powered Analytics

- **Predictive Models:** Vessel delay and route disruption forecasting
- **Impact Analysis:** Economic and operational effect assessment
- **Pattern Recognition:** Historical trend analysis and anomaly detection
- **Risk Scoring:** Automated threat level evaluation

### Professional UI/UX

- **Enterprise Design:** SAP-style professional interface
- **Interactive Maps:** Leaflet.js with custom maritime overlays
- **Data Tables:** Sortable, filterable enterprise data grids
- **Mobile Optimization:** Responsive design for all devices

## Technical Specifications

### Performance Metrics

- **API Response Time:** <200ms average
- **Database Queries:** Optimized with indexing and caching
- **Real-time Updates:** 30-second refresh intervals
- **System Uptime:** 98.9% reliability target

### Data Quality Standards

- **Coordinate Accuracy:** Validated ocean-only vessel positioning
- **Source Verification:** Multiple authoritative data sources
- **Duplicate Prevention:** Advanced deduplication algorithms
- **Confidence Scoring:** 80%+ minimum for AI predictions

### Security & Compliance

- **CORS Protection:** Secure cross-origin requests
- **Input Validation:** Sanitized data processing
- **Rate Limiting:** API abuse prevention
- **Error Handling:** Graceful failure management

## Deployment Architecture

### Development Environment

- **Frontend:** React with Vite development server
- **Backend:** FastAPI with Uvicorn ASGI server
- **Database:** PostgreSQL with real-time connections
- **AI Processing:** TensorFlow with GPU acceleration support

### Production Considerations

- **Load Balancing:** Multiple API server instances
- **Database Scaling:** Read replicas and connection pooling
- **CDN Integration:** Static asset optimization
- **Monitoring:** Real-time health checks and alerting

## Data Flow

1. **External Sources** → RSS feeds, APIs, weather services
2. **Data Processing** → Parsing, validation, coordinate verification
3. **Database Storage** → PostgreSQL with structured schemas
4. **AI Analysis** → Pattern recognition and prediction generation
5. **API Serving** → Real-time data delivery to frontend
6. **User Interface** → Interactive visualization and analytics

## Future Enhancements

### Planned Features

- **Satellite Integration:** Real-time port imagery via satellite feeds
- **Blockchain Integration:** Supply chain transparency and verification
- **Advanced AI Models:** Deep learning for complex trade predictions
- **Mobile Application:** Native iOS/Android applications
- **Enterprise SSO:** Corporate authentication integration

### Scalability Roadmap

- **Microservices:** Service decomposition for better scaling
- **Container Orchestration:** Kubernetes deployment
- **Message Queues:** Asynchronous data processing
- **Multi-region:** Global deployment for reduced latency

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*Last Updated: January 2025 Version: 2.1.0 Architecture Review: Complete*