Technical Presentation: House Price Prediction API

1. Project Overview

Deployed a machine learning model for house price prediction as a scalable RESTful service. Key deliverables: API, test script, and model performance evaluation.

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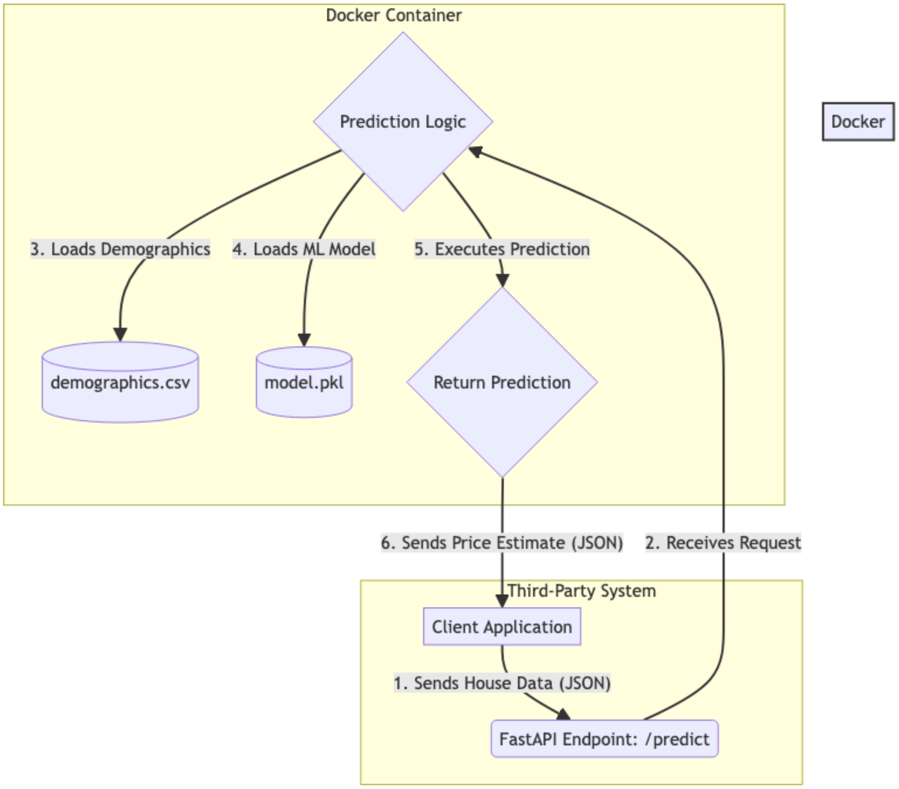
2. Architecture and Design Choices

Simple, robust architecture using modern open-source tools.



- **API Framework: FastAPI**
  - High performance, asynchronous support, automatic validation, OpenAPI documentation.
- **Containerization: Docker**
  - Consistent environment for development/deployment, simplified dependency management.

- **Data Handling:**
  - House data sent via JSON to `/predict` endpoint.
  - `zipcode_demographics.csv` loaded into pandas DataFrame at startup.
  - **Production Consideration:** Migrate demographic data to PostgreSQL for scalability.

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3. Model Evaluation and Improvement

Initial Model

- **Algorithm:** `KNeighborsRegressor` with `RobustScaler`.
- **Features:** Small subset of numeric columns.
- **Performance:**
  - **R-squared:** 0.7284
  - **Mean Absolute Error:** $102,337.19

Improved Model

Developed an improved model per project recommendations.

- **Algorithm:** `GradientBoostingRegressor`
  - More powerful ensemble method with higher accuracy than k-NN.
- **Feature Engineering:**
  - Used all available numeric features.
  - Extracted `sale_year` and `sale_month` from `date` field.
- **Performance:**
  - **R-squared: 0.8804** (+21% improvement)
  - **Mean Absolute Error: $69,841.29** (32% improvement)

Substantial improvement in prediction accuracy.

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4. Scalability and Future Work

- **Scalability:** Containerized API allows easy scaling. Kubernetes deploys multiple instances with load balancing for high availability.

- **Model Versioning:** Current setup loads model at startup. Robust strategy:

  1. Store model artifacts in MLflow or S3.
  2. Create `/-/reload_model` endpoint for zero-downtime updates.

- **Future Improvements:**

  - Hyperparameter tuning with GridSearchCV.
  - Advanced feature engineering for geographical data.

5. Cloud Deployment Strategy

Production deployment in the cloud using:

Container Orchestration

- **Kubernetes** (preferred) or **AWS ECS**
  - Horizontal scaling based on demand
  - High availability through replica management
  - Rolling updates for zero-downtime deployments
  - Key Components: Deployments, Services, Ingress, ConfigMaps, Secrets

Cloud Provider Options

- **AWS:** EKS, ALB, S3, CloudWatch
- **GCP:** GKE, Cloud Load Balancing, Cloud Storage, Cloud Monitoring
- **Azure:** AKS, Application Gateway, Azure Blob Storage, Azure Monitor

Model Registry and Versioning

- **MLflow** (recommended):
  - Model registry with version control
  - Performance metrics comparison
  - Model stage transitions
- **Alternatives:** S3/GCS/Azure Blob with manual versioning, DVC, Weights & Biases

CI/CD Pipeline

- **GitHub Actions** or **GitLab CI/CD**:
  - Stages: Testing, Building, Security Scanning, Deployment
  - Tools: pytest, Docker Hub/ECR, kubectl, notifications

Monitoring and Observability

- **APM:** Prometheus, Grafana
- **Metrics:** Response times, throughput, error rates, resource utilization
- **Logging:** ELK Stack or similar solutions
- **Health Checks:** Liveness/readiness probes, downtime alerts

API Authentication and Security

- **Methods:** JWT, API Keys, OAuth2
- **Implementation:** FastAPI dependency injection, rate limiting
- **Best Practices:** TLS encryption, security scanning, least privilege

Auto-scaling

- Kubernetes Horizontal Pod Autoscaler (HPA)
- Scale based on CPU utilization or custom metrics (requests/second, response time)

Additional Considerations

- **Backup/Recovery:** Regular backups, cross-region replication
- **Cost Optimization:** Resource tuning, spot instances, auto-scaling policies

Comprehensive cloud deployment strategy ensures scalability, reliability, and maintainability.