AI Project Cycle for Manufacturing

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Machine Parts Failure Prediction System

ML Canvas for Predictive Maintenance in Manufacturing

PREDICT (HOW)

Decisions

Primary decision: Prioritize maintenance tasks based on predicted machine part failure risk.

Daily operations: Sort machine parts into high, medium, and low risk categories for maintenance scheduling.

Resource allocation: Optimize maintenance staff and replacement parts inventory based on risk forecasts.

Production planning: Adjust schedules for preventive maintenance of high-risk parts.

Budget allocation: Justify maintenance budget with predictive analytics of failure patterns and savings.

ML Tasks

Task type: Binary classification with probability calibration

Inputs:

- Real-time sensor readings (temperature, vibration)
- Historical maintenance records
- Operational parameters (run time, load)
- Environmental conditions

Outputs:

- Probability of failure within 7, 14 and 30 days
- Estimated remaining useful life
- Confidence interval for predictions

LEARN (HOW)

Value Propositions

Primary value: Reduce unplanned downtime by 40%.

Cost savings: Decrease maintenance costs by 25% through optimized scheduling.

Production: Increase equipment effectiveness (OEE) by 15%.

Parts optimization: Extend machine part lifetime by 20%.

Safety: Reduce equipment-related incidents by 30%.

Stakeholders: Maintenance team, production managers, operations, financial officers.

Data Source

Internal sources:

- SCADA system and PLC controllers
- IoT sensors (temperature, vibration, pressure)
- Computerized Maintenance Management System
- Enterprise Resource Planning (ERP) system
- Historical failure records and maintenance logs
- Quality control and inspection reports

External sources:

- Equipment manufacturer specifications
- Industry reliability benchmarks
- Weather and environmental data

GOAL (WHAT, WHY, WHO)

Making Predictions

Prediction frequency:

- Real-time anomaly detection for critical parts
- Daily batch predictions for planning
- Weekly risk assessment reports

Prediction workflow:

1. Data collection from sensors and systems
2. Feature extraction and preprocessing
3. Model inference for failure probabilities
4. Risk categorization and prioritization
5. Alert generation for high-risk components
6. Maintenance work order creation in CMMS

Offline Evaluation

Model performance metrics:

- Precision: Minimize false alarms
- Recall: Capture >95% of actual failures
- F1-score: Balance precision and recall
- ROC-AUC and PR-AUC for thresholds
- Log loss for probability calibration

Business metrics:

- Maintenance cost reduction
- Mean time between failures improvement
- Lead time advantage (prediction vs. failure)
- ROI calculation (cost vs. savings)

Features

Raw sensor features:

- Vibration amplitude and frequency spectrum
- Temperature patterns and anomalies
- Acoustic signatures and ultrasonic data
- Current draw and power consumption
- Pressure fluctuations and fluid flow rates

Engineered features:

- Statistical moments (mean, variance, skewness)
- Frequency domain transforms (FFT, wavelets)
- Rolling windows and trend indicators
- Correlation matrices between sensors
- Operational context (load, speed, duty cycle)

Building Models

Model development:

- Train on 18 months of historical data
- Use ensemble methods (RF, XGBoost, LSTM)
- Separate models for different machine types
- Address class imbalance with SMOTE

Model updating:

- Incremental learning with new data monthly
- Full retraining quarterly
- Automated hyperparameter optimization
- A/B testing before deployment

EVALUATE (HOW WELL)

Evaluation and Monitoring

Model Performance Monitoring:

- Daily tracking of accuracy metrics
- Weekly assessment of false positives/negatives
- Model drift detection via statistical tests
- Auto-retraining when performance degrades

Business Impact Assessment:

- Monthly calculation of cost savings
- Quarterly review of downtime reduction
- Part lifespan extension measurement
- Production efficiency improvement tracking

System Health Monitoring:

- Data quality and completeness checks
- Sensor failure detection and alerting
- Feature importance stability analysis
- Feedback from technicians on accuracy