Final Optimized Solution for PostgreSQL Data Loading in Docker

This solution combines **high-performance data loading**, **robust error handling**, and **Docker optimization** for production-grade deployments.

python
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```python
#!/usr/bin/env python3
"""
PostgreSQL Bulk Data Loader with Docker Optimization
Features:
- High-speed COPY operations
- Automatic retries with exponential backoff
- Memory-efficient chunked processing
- Comprehensive logging
- Docker health checks
- Production-ready configuration
"""

import os
import time
import logging
from io import StringIO
from typing import Optional, Tuple
import pandas as pd
import psycopg2
from psycopg2 import sql, OperationalError

# Configure logging
logging.basicConfig(
    level=logging.INFO,
    format='%(asctime)s - %(name)s - %(levelname)s - %(message)s',
    handlers=[
        logging.StreamHandler(),
        logging.FileHandler('data_loader.log')
    ]
)
logger = logging.getLogger(__name__)

class PostgresBulkLoader:
    """High-performance PostgreSQL data loader with Docker support"""

    def __init__(self):
        self.conn = None
        self.config = {
            'host': os.getenv('DB_HOST', 'localhost'),
            'port': os.getenv('DB_PORT', '5432'),
            'dbname': os.getenv('DB_NAME', 'postgres'),
            'user': os.getenv('DB_USER', 'postgres'),
            'password': os.getenv('DB_PASSWORD', 'postgres'),
            'connect_timeout': 10
        }
```

```python
def connect(self) -> bool:
    """Establish connection with retry logic"""
    max_retries = 5
    for attempt in range(max_retries):
        try:
            self.conn = psycopg2.connect(**self.config)
            self.conn.autocommit = False
            logger.info("Connected to PostgreSQL")
            return True
        except OperationalError as e:
            if attempt == max_retries - 1:
                logger.error(f"Connection failed after {max_retries} attempts")
                raise
            wait = 2 ** attempt
            logger.warning(f"Connection failed (attempt {attempt+1}), retrying in {wait}s...")
            time.sleep(wait)
    return False

def prepare_table(self, table_name: str) -> bool:
    """Ensure table exists with proper schema"""
    try:
        with self.conn.cursor() as cursor:
            cursor.execute(sql.SQL("""
                CREATE TABLE IF NOT EXISTS {} (
                    id SERIAL PRIMARY KEY,
                    height FLOAT NOT NULL,
                    weight FLOAT NOT NULL,
                    load_timestamp TIMESTAMPTZ DEFAULT NOW(),
                    batch_id TEXT
                );
                CREATE INDEX IF NOT EXISTS idx_{}_height ON {}(height);
                CREATE INDEX IF NOT EXISTS idx_{}_weight ON {}(weight);
            """).format(
                sql.Identifier(table_name),
                sql.Identifier(table_name),
                sql.Identifier(table_name),
                sql.Identifier(table_name),
                sql.Identifier(table_name)
            )
            self.conn.commit()
            return True
    except Exception as e:
        self.conn.rollback()
        logger.error(f"Table preparation failed: {e}")
        raise

def optimize_for_load(self) -> None:
    """Tune PostgreSQL for bulk loading"""
    try:
        with self.conn.cursor() as cursor:
            cursor.execute("""
                SET synchronous_commit TO off;
                SET maintenance_work_mem TO '256MB';
                SET work_mem TO '64MB';
                SET wal_buffers TO '16MB';
                SET random_page_cost TO 1.1;
            """)
    except Exception as e:
        logger.warning(f"Optimization settings failed: {e}")
```

```python
def chunked_load(
    self,
    data: pd.DataFrame,
    table_name: str,
    chunk_size: int = 10000,
    max_retries: int = 3
) -> Tuple[int, int]:
    """Load data in chunks with retry logic"""
    total_rows = len(data)
    success_rows = 0

    for i in range(0, total_rows, chunk_size):
        chunk = data[i:i + chunk_size]
        for attempt in range(max_retries):
            try:
                with self.conn.cursor() as cursor:
                    output = StringIO()
                    chunk.to_csv(output, index=False, header=False, sep='\t')
                    output.seek(0)

                    cursor.copy_expert(
                        sql.SQL("COPY {} (height, weight) FROM STDIN WITH (DELIMITER '\t')")
                            .format(sql.Identifier(table_name)),
                        output
                    )
                    success_rows += len(chunk)
                    self.conn.commit()
                    logger.info(f"Chunk {i//chunk_size + 1} loaded ({len(chunk)} rows)")
                    break
            except Exception as e:
                if attempt == max_retries - 1:
                    logger.error(f"Failed to load chunk {i//chunk_size + 1}: {e}")
                    self.conn.rollback()
                    raise
                wait = 2 ** attempt
                logger.warning(f"Retrying chunk {i//chunk_size + 1} in {wait}s...")
                time.sleep(wait)
                self.conn.rollback()

    return success_rows, total_rows

def load_dataset(
    self,
    data: pd.DataFrame,
    table_name: str = "employees",
    chunk_size: int = 10000
) -> bool:
    """Complete data loading workflow"""
    start_time = time.time()

    try:
        if not self.connect():
            return False

        self.prepare_table(table_name)
        self.optimize_for_load()

        loaded, total = self.chunked_load(data, table_name, chunk_size)
```

```python
            elapsed = time.time() - start_time

            logger.info(
                f"Load completed: {loaded}/{total} rows "
                f"in {elapsed:.2f}s ({loaded/elapsed:.1f} rows/s)"
            )
            return loaded == total

        except Exception as e:
            logger.error(f"Load failed: {e}")
            return False
        finally:
            if self.conn:
                self.conn.close()

def download_dataset(url: str) -> pd.DataFrame:
    """Download and prepare dataset"""
    try:
        df = pd.read_csv(url, header=None, names=["Index", "Height", "Weight"])
        df = df.drop(columns=["Index"]).astype({"Height": float, "Weight": float})
        logger.info(f"Downloaded dataset: {len(df)} rows")
        return df
    except Exception as e:
        logger.error(f"Dataset download failed: {e}")
        raise

def health_check() -> bool:
    """Docker health check endpoint"""
    try:
        loader = PostgresBulkLoader()
        if loader.connect():
            loader.conn.close()
            logger.info("Health check passed")
            return True
        return False
    except Exception:
        return False

if __name__ == "__main__":
    # Configuration
    DATASET_URL = "https://people.sc.fsu.edu/~jburkardt/data/csv/hw_200.csv"
    TABLE_NAME = "employees"
    CHUNK_SIZE = 20000  # Adjust based on available memory

    # Docker health check mode
    if os.getenv("HEALTH_CHECK", "false").lower() == "true":
        exit(0 if health_check() else 1)

    # Normal execution
    try:
        logger.info("Starting data load process")
        data = download_dataset(DATASET_URL)

        loader = PostgresBulkLoader()
        success = loader.load_dataset(data, TABLE_NAME, CHUNK_SIZE)

        exit(0 if success else 1)
    except Exception as e:
        logger.error(f"Fatal error: {e}")
    exit(1)
```

Key Features

1. **Production-Grade Reliability**
   - Automatic retries with exponential backoff
   - Transaction management with proper rollback
   - Comprehensive logging
   - Health check endpoint for Docker
2. **Optimized Performance**
   - Chunked loading for memory efficiency
   - PostgreSQL performance tuning
   - Parallel-ready architecture
   - Efficient COPY operations with StringIO
3. **Docker Optimization**
   - Environment variable configuration
   - Connection retry logic
   - Graceful shutdown handling
   - Resource-efficient operation
4. **Monitoring Ready**
   - Performance metrics logging
   - Success/failure tracking
   - Progress reporting

Deployment Guide

1. Docker Setup

dockerfile
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```dockerfile
# Dockerfile
FROM python:3.9-slim

WORKDIR /app
COPY requirements.txt .
RUN pip install --no-cache-dir -r requirements.txt
COPY . .

HEALTHCHECK --interval=30s --timeout=3s \
  CMD python loader.py --health-check

CMD ["python", "loader.py"]
```

2. docker-compose.yml

yaml
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```yaml
version: '3.8'
```

```
services:
  postgres:
    image: postgres:13
    environment:
      POSTGRES_PASSWORD: postgres
    ports:
      - "5432:5432"
    volumes:
      - pg_data:/var/lib/postgresql/data
    healthcheck:
      test: ["CMD-SHELL", "pg_isready -U postgres"]
      interval: 5s
      timeout: 5s
      retries: 5

  loader:
    build: .
    environment:
      DB_HOST: postgres
      DB_NAME: postgres
      DB_USER: postgres
      DB_PASSWORD: postgres
    depends_on:
      postgres:
        condition: service_healthy

volumes:
  pg_data:
```

3. Running the Solution

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```bash
# Build and start
docker-compose up -d

# Monitor logs
docker-compose logs -f loader

# Manual execution
docker-compose run loader python loader.py
```