

# BinBot Implementation Plan

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## Overview

This plan breaks down the BinBot implementation into small, testable phases. Each phase builds incrementally and can be tested independently. UI remains minimal until the final phase.

## Phase 1: Foundation Setup (Core Infrastructure)

**Goal:** Basic project structure with minimal working FastAPI server

Tasks:

### 1. Create project structure

- Create all required directories and files
- Set up basic `requirements.txt` (include openai or google-generativeai)
- Create minimal `config.yaml` with external LLM configuration
- Create basic `api_schemas.py` with Pydantic models

### 2. Basic FastAPI server

- Minimal `app.py` with FastAPI initialization
- Basic `/health` endpoint that returns system status
- Configuration loading from `config.yaml`
- Environment variable support for API keys
- Basic error handling structure

### 3. Docker setup

- Create `Dockerfile` for Python 3.11 base
- Create `start.sh` script
- Test container builds and runs

### 4. Minimal frontend

- Basic `index.html` with no styling
- Single text input and submit button
- JavaScript to call `/health` endpoint

Testing:

- Container builds successfully
- FastAPI server starts and responds to `/health`
- Frontend loads and can call backend
- Configuration loads correctly

## Phase 2: ChromaDB Integration (Database Layer)

**Goal:** ChromaDB working with basic collections and persistence

Tasks:

### 1. ChromaDB initialization

- Add ChromaDB to requirements
- Initialize persistent ChromaDB client
- Create **inventory** and **audit\_log** collections
- Add embedding model configuration

### 2. Basic data models

- Define item schema in ChromaDB
- Test adding/retrieving simple documents
- Implement basic error handling for DB operations

### 3. Health check enhancement

- Add ChromaDB status to **/health** endpoint
- Test database connectivity

Testing:

- ChromaDB initializes and persists data
  - Collections are created successfully
  - Basic documents can be added and retrieved
  - Health check reports database status
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## Phase 3: Basic Search Functionality (Core Feature)

**Goal:** Simple text-based search without LLM integration

Tasks:

### 1. Search endpoint

- Implement **GET /search** endpoint
- Use simple text matching (no embeddings yet)
- Return standardized response format
- Add basic pagination

### 2. Frontend search

- Add search form to frontend
- Display search results in plain text list
- Handle empty results gracefully

### 3. Test data

- Create script to populate test inventory data
- Add various items across different bins

Testing:

- Search endpoint returns results
- Frontend displays search results
- Pagination works correctly
- Empty searches handled properly

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## Phase 4: LLM Integration (AI Layer)

**Goal:** Connect to external LLM service (OpenAI/Gemini) for embedding generation and search

Tasks:

### 1. LLM client setup

- Add OpenAI or Google AI client to backend
- Implement API key configuration via environment variables
- Add error handling for API rate limits and failures
- Test basic LLM connectivity

### 2. Embedding generation

- Implement embedding generation using external API (e.g., OpenAI text-embedding-ada-002)
- Update search to use vector similarity
- Add embedding model version tracking
- Implement caching to reduce API calls

### 3. Enhanced search

- Replace text matching with vector search
- Implement similarity scoring
- Add confidence thresholds

Testing:

- External LLM API connection works
- Embeddings are generated successfully via API
- Vector search returns relevant results
- Error handling works for API failures and rate limits
- Embedding caching reduces redundant API calls

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## Phase 5: Add Items Functionality (CRUD Operations)

**Goal:** Users can add items to inventory

Tasks:

**1. Add endpoint**

- Implement **POST /add** endpoint
- Handle single item additions
- Generate embeddings for new items
- Store in ChromaDB with metadata

**2. Frontend add form**

- Add simple form with item name and bin number
- Handle form submission
- Display success/error messages

**3. Audit logging**

- Implement basic audit log entries
- Track item additions with timestamps

Testing:

- Items can be added successfully
  - Embeddings are generated and stored
  - Audit log captures additions
  - Frontend form works correctly
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## Phase 6: Remove Items Functionality

**Goal:** Users can remove items from inventory

Tasks:

**1. Remove endpoint**

- Implement **POST /remove** endpoint
- Search for items to remove
- Handle item deletion from ChromaDB

**2. Basic disambiguation**

- Return multiple matches when found
- Simple list format for user selection

**3. Frontend remove interface**

- Add remove form
- Display disambiguation options as simple list

- Handle confirmation flow

Testing:

- Items can be removed successfully
  - Disambiguation works for multiple matches
  - Audit log captures removals
  - Frontend handles disambiguation flow
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## Phase 7: Move Items Functionality

**Goal:** Users can move items between bins

Tasks:

### 1. Move endpoint

- Implement **POST** `/move` endpoint
- Update `bin_id` metadata
- Handle disambiguation like remove

### 2. Frontend move interface

- Add move form with source/target bins
- Reuse disambiguation interface

Testing:

- Items can be moved between bins
  - Bin metadata updates correctly
  - Audit log captures moves
  - Disambiguation works for moves
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## Phase 8: Context Management (Session State)

**Goal:** Multi-turn conversations with context awareness

Tasks:

### 1. Session management

- Implement in-memory session store
- Track current `bin_id` per session
- Add session timeout handling

### 2. Context-aware operations

- Modify add/remove/move to use context
- Auto-apply `bin_id` from context

- Handle context reset commands

### 3. Frontend session handling

- Track session state in JavaScript
- Display current context to user

Testing:

- Context is maintained across requests
  - Operations use context appropriately
  - Context resets work correctly
  - Frontend shows current context
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## Phase 9: Bulk Operations & Transactions

**Goal:** Handle multiple items in single operations

Tasks:

### 1. Bulk add functionality

- Parse multiple items from single input
- Implement transaction management
- Add rollback on failures

### 2. Transaction handling

- Generate bulk transaction IDs
- Atomic commit/rollback operations
- Enhanced audit logging for bulk ops

Testing:

- Multiple items can be added at once
  - Transactions rollback on failures
  - Audit log tracks bulk operations
  - Performance is acceptable for bulk ops
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## Phase 10: Natural Language Text Interface

**Goal:** Create a simple text-based interface for natural language inventory commands

Tasks:

### 1. Natural language command parser

- Create LLM-based command interpretation
- Parse commands like "add bolts to bin 3"

- Extract action, items, and locations
- Handle context and follow-up commands

## 2. Command processing engine

- Map parsed commands to API calls
- Implement context retention ("also add nuts")
- Support multiple command types (add, remove, move, search)
- Add command validation and confirmation

## 3. Simple text interface frontend

- Create chat-like interface for command input
- Display command results and confirmations
- Show command history
- Add help and examples

## 4. Context-aware processing

- Remember previous bin/item context
- Support follow-up commands
- Handle ambiguous references
- Maintain conversation state

Commands to Support:

- "add bolts to bin 3" → Parse item, action, location
- "also add nuts" → Use previous context (bin 3)
- "remove wires from bin 2" → Remove operation
- "move screws from bin 1 to bin 5" → Move operation
- "search for electronics" → Search operation
- "what's in bin 7?" → List bin contents
- "undo last command" → Rollback functionality

Testing:

- Test basic command parsing accuracy
- Test context retention between commands
- Test error handling for ambiguous commands
- Test all supported command types
- Test complex multi-step operations

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## Phase 11: Voice Interface (Web Speech API)

**Goal:** Voice input for natural interaction

Tasks:

### 1. Frontend voice integration

- Add microphone button
- Implement Web Speech API
- Convert speech to text for existing endpoints

## 2. **Voice feedback**

- Add text-to-speech for responses
- Handle voice command errors

Testing:

- Voice input works in supported browsers
- Speech is converted to text accurately
- Voice commands trigger correct actions
- Fallback works for unsupported browsers

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## Phase 12: Advanced Features & Polish

**Goal:** Complete remaining advanced features

Tasks:

### 1. **Advanced disambiguation**

- Improve similarity scoring
- Better disambiguation UI
- Confidence score display

### 2. **Enhanced error handling**

- Comprehensive error messages
- Retry mechanisms
- Better fallback strategies

### 3. **Performance optimization**

- Embedding caching
- Query optimization
- Response time improvements

Testing:

- All error scenarios handled gracefully
- Performance meets requirements
- Advanced features work reliably

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## Phase 13: UI Enhancement & Final Polish

**Goal:** Improve user interface and experience



Tasks:

### 1. UI styling

- Add Tailwind CSS
- Improve layout and design
- Add responsive design

### 2. UX improvements

- Better loading states
- Improved feedback messages
- Keyboard shortcuts

### 3. Final testing

- End-to-end testing
- Performance testing
- User acceptance testing

Testing:

- UI is polished and responsive
  - All features work together seamlessly
  - Performance is acceptable
  - User experience is smooth
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## Phase 14: Undo Functionality

**Goal:** Users can undo recent operations

Tasks:

### 1. Undo endpoint

- Implement **POST** `/undo` endpoint
- Restore previous states from audit log
- Handle bulk operation undos

### 2. Frontend undo interface

- Add prominent undo button
- Show what will be undone
- Confirm undo operations

Testing:

- Single operations can be undone
- Bulk operations can be undone atomically
- Undo creates proper audit entries

- Frontend undo interface works
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## Phase 15: Image Support (Multimodal)

**Goal:** Users can attach images to items

Tasks:

### 1. Image upload handling

- Add file upload to add endpoint
- Store images in persistent volume
- Generate image paths in metadata

### 2. Basic image display

- Show images in search results
- Handle missing images gracefully

### 3. Frontend image support

- Add file input to add form
- Display images in results

Testing:

- Images can be uploaded and stored
  - Images display in search results
  - File paths are stored correctly
  - Missing images handled gracefully
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## Testing Strategy for Each Phase

### Unit Testing

- Test individual functions and endpoints
- Mock external dependencies (Ollama, ChromaDB)
- Validate request/response schemas

### Integration Testing

- Test API endpoints with real ChromaDB
- Test frontend-backend integration
- Test Docker container functionality

### Manual Testing

- Test user workflows manually
- Verify error handling

- Test edge cases

## Acceptance Criteria

Each phase must pass all tests before proceeding to the next phase.