YouTube Companion Web App: Technical Requirements

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This document outlines the technical requirements for building a YouTube companion web app powered by AI agents with social features. It covers the architecture, AI agent frameworks, database schema, authentication, and implementation details necessary for development.

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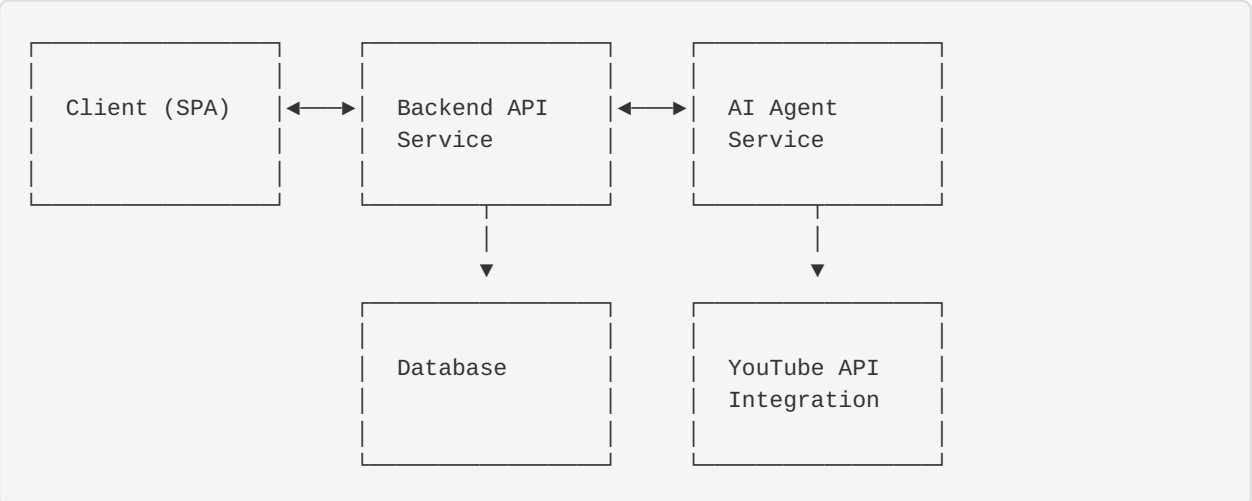
1. System Architecture

The YouTube companion web app will follow a modern, scalable architecture with the following components:

1.1 High-Level Architecture



1.2 Component Descriptions

1. **Client (SPA)**: A React-based Single Page Application that provides the user interface for interacting with YouTube content, AI agents, and social features.

2. **Backend API Service**: A Node.js/Express or Python/FastAPI service that handles authentication, data processing, and communication between the client, database, and AI agent service.
3. **AI Agent Service**: A dedicated service built on a multi-agent framework that manages AI agents, their interactions, and learning processes.
4. **Database**: A combination of relational and vector databases to store user data, agent data, and embeddings for content analysis.
5. **YouTube API Integration**: A service component that handles communication with the YouTube Data API, managing quotas and caching responses.

2. AI Agent Framework Selection

Based on our research, we recommend using **CrewAI** as the primary framework for implementing AI agents in the YouTube companion app, with **LangGraph** for specific complex workflows.

2.1 Framework Comparison

Framework	Strengths	Limitations	Fit for Our Use Case
CrewAI	Role-based agents, team collaboration, rapid development	Early-stage development	Excellent for YouTube companion with multiple specialized agents
LangGraph	Dynamic workflows, decision-making, visual debugging	Setup complexity	Good for complex recommendation and content analysis flows
AutoGen	Multi-agent collaboration, enterprise reliability	Coordination complexity	Strong alternative, especially for scaling
LangChain	Flexibility, extensive tooling, community support	Debugging challenges	Good foundation but less specialized for our multi-agent needs

2.2 Recommended Agent Architecture

We recommend implementing a team of specialized AI agents using CrewAI:

1. **Content Analyzer Agent**: Processes video metadata, captions, and comments to extract key information.
2. **Recommendation Agent**: Generates personalized video recommendations based on user preferences and viewing history.
3. **Summarization Agent**: Creates concise summaries of video content for quick consumption.
4. **Social Facilitator Agent**: Manages sharing and collaborative features between users and their agents.
5. **Learning Coordinator Agent**: Orchestrates knowledge sharing between agents and implements collaborative learning.

2.3 Agent Communication Protocol

Agents will communicate using a standardized JSON-based protocol with the following structure:

```
{
  "messageId": "unique-message-id",
  "fromAgent": "agent-identifier",
  "toAgent": "agent-identifier",
  "messageType": "request|response|notification",
  "content": {
    "action": "action-name",
    "parameters": {},
    "data": {}
  },
  "timestamp": "ISO-timestamp"
}
```

3. Database Schema

The database schema will support user profiles, agent data, content interactions, and social features.

3.1 Core Entities

Users Table

```
CREATE TABLE Users (
    UserID VARCHAR(36) PRIMARY KEY,
    Username VARCHAR(50) UNIQUE NOT NULL,
    Email VARCHAR(255) UNIQUE NOT NULL,
    PasswordHash VARCHAR(255) NOT NULL,
    CreatedAt TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    LastLogin TIMESTAMP,
    ProfilePicture VARCHAR(255),
    IsActive BOOLEAN DEFAULT TRUE
);
```

UserPreferences Table

```
CREATE TABLE UserPreferences (
    PreferenceID VARCHAR(36) PRIMARY KEY,
    UserID VARCHAR(36) NOT NULL,
    PreferenceKey VARCHAR(50) NOT NULL,
    PreferenceValue TEXT,
    LastUpdated TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    FOREIGN KEY (UserID) REFERENCES Users(UserID),
    UNIQUE (UserID, PreferenceKey)
);
```

Agents Table

```
CREATE TABLE Agents (
    AgentID VARCHAR(36) PRIMARY KEY,
    UserID VARCHAR(36) NOT NULL,
    AgentType VARCHAR(50) NOT NULL,
    AgentName VARCHAR(100) NOT NULL,
    Configuration JSONB,
    CreatedAt TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    LastActive TIMESTAMP,
    VisualAssets JSONB,
    FOREIGN KEY (UserID) REFERENCES Users(UserID)
);
```

AgentMemories Table

```
CREATE TABLE AgentMemories (
    MemoryID VARCHAR(36) PRIMARY KEY,
    AgentID VARCHAR(36) NOT NULL,
    MemoryType VARCHAR(50) NOT NULL,
    Content TEXT NOT NULL,
    Metadata JSONB,
    CreatedAt TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    Importance FLOAT DEFAULT 0.5,
    FOREIGN KEY (AgentID) REFERENCES Agents(AgentID)
);
```

VideoInteractions Table

```
CREATE TABLE VideoInteractions (
    InteractionID VARCHAR(36) PRIMARY KEY,
    UserID VARCHAR(36) NOT NULL,
    VideoID VARCHAR(20) NOT NULL,
    InteractionType VARCHAR(50) NOT NULL,
    Timestamp TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    Data JSONB,
    FOREIGN KEY (UserID) REFERENCES Users(UserID)
);
```

AgentInteractions Table

```
CREATE TABLE AgentInteractions (
    InteractionID VARCHAR(36) PRIMARY KEY,
    FromAgentID VARCHAR(36) NOT NULL,
    ToAgentID VARCHAR(36) NOT NULL,
    InteractionType VARCHAR(50) NOT NULL,
    Content TEXT,
    Metadata JSONB,
    Timestamp TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    FOREIGN KEY (FromAgentID) REFERENCES Agents(AgentID),
    FOREIGN KEY (ToAgentID) REFERENCES Agents(AgentID)
);
```

SocialConnections Table

```
CREATE TABLE SocialConnections (
    ConnectionID VARCHAR(36) PRIMARY KEY,
    UserID1 VARCHAR(36) NOT NULL,
    UserID2 VARCHAR(36) NOT NULL,
    ConnectionType VARCHAR(50) NOT NULL,
    Status VARCHAR(20) NOT NULL,
    CreatedAt TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    LastInteraction TIMESTAMP,
    FOREIGN KEY (UserID1) REFERENCES Users(UserID),
    FOREIGN KEY (UserID2) REFERENCES Users(UserID),
    UNIQUE (UserID1, UserID2, ConnectionType)
);
```

SharedDiscoveries Table

```
CREATE TABLE SharedDiscoveries (
    DiscoveryID VARCHAR(36) PRIMARY KEY,
    AgentID VARCHAR(36) NOT NULL,
    DiscoveryType VARCHAR(50) NOT NULL,
    Content TEXT NOT NULL,
    Metadata JSONB,
    CreatedAt TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    IsPublic BOOLEAN DEFAULT FALSE,
    FOREIGN KEY (AgentID) REFERENCES Agents(AgentID)
);
```

ShopItems Table

```
CREATE TABLE ShopItems (
    ItemID VARCHAR(36) PRIMARY KEY,
    ItemType VARCHAR(50) NOT NULL,
    Name VARCHAR(100) NOT NULL,
    Description TEXT,
    Price DECIMAL(10, 2) NOT NULL,
    AssetURL VARCHAR(255),
    Metadata JSONB,
    IsActive BOOLEAN DEFAULT TRUE
);
```

UserInventory Table

```
CREATE TABLE UserInventory (
    InventoryID VARCHAR(36) PRIMARY KEY,
    UserID VARCHAR(36) NOT NULL,
    ItemID VARCHAR(36) NOT NULL,
    AcquiredAt TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    IsEquipped BOOLEAN DEFAULT FALSE,
    FOREIGN KEY (UserID) REFERENCES Users(UserID),
    FOREIGN KEY (ItemID) REFERENCES ShopItems(ItemID),
    UNIQUE (UserID, ItemID)
);
```

3.2 Vector Database for Content

For storing and retrieving video content embeddings, we recommend using PgVector (PostgreSQL extension) or a dedicated vector database like Pinecone:

```
CREATE EXTENSION IF NOT EXISTS vector;

CREATE TABLE VideoEmbeddings (
    VideoID VARCHAR(20) PRIMARY KEY,
    Title VARCHAR(255) NOT NULL,
    Description TEXT,
    Embedding vector(1536),
    Metadata JSONB,
    LastUpdated TIMESTAMP DEFAULT CURRENT_TIMESTAMP
);

CREATE INDEX video_embedding_idx ON VideoEmbeddings USING ivfflat (Embedding vec-
tor_cosine_ops);
```

4. Authentication System

The YouTube companion web app will implement a secure password-based authentication system with the following features:

4.1 Authentication Flow

1. **Registration**: Users provide username, email, and password
2. **Login**: Username/email and password verification
3. **Session Management**: JWT (JSON Web Tokens) for maintaining authenticated sessions
4. **Password Reset**: Secure email-based password reset functionality

4.2 Security Implementation

• **Password Storage**: Passwords will be hashed using bcrypt with appropriate salt rounds
• **HTTPS**: All communications will be encrypted using HTTPS
• **JWT Configuration**:
• Short-lived access tokens (15-30 minutes)
• Refresh tokens stored in HttpOnly, Secure cookies
• Token rotation on refresh
• **Protection Against Common Attacks**:
• XSS: Content Security Policy (CSP) headers
• CSRF: Anti-CSRF tokens and SameSite cookies
• Brute Force: Rate limiting and account lockouts

4.3 Authentication Code Example

```
// Example Node.js authentication middleware
const jwt = require('jsonwebtoken');
const bcrypt = require('bcrypt');

// Password hashing
async function hashPassword(password) {
  const saltRounds = 12;
  return await bcrypt.hash(password, saltRounds);
}

// Password verification
async function verifyPassword(password, hashedPassword) {
  return await bcrypt.compare(password, hashedPassword);
}

// JWT token generation
function generateTokens(userId) {
  const accessToken = jwt.sign(
    { userId },
    process.env.JWT_ACCESS_SECRET,
    { expiresIn: '15m' }
  );

  const refreshToken = jwt.sign(
    { userId },
    process.env.JWT_REFRESH_SECRET,
    { expiresIn: '7d' }
  );

  return { accessToken, refreshToken };
}

// Authentication middleware
function authenticateToken(req, res, next) {
  const authHeader = req.headers['authorization'];
  const token = authHeader && authHeader.split(' ')[1];

  if (!token) return res.sendStatus(401);

  jwt.verify(token, process.env.JWT_ACCESS_SECRET, (err, user) => {
    if (err) return res.sendStatus(403);
    req.user = user;
    next();
  });
}
```

5. Frontend Requirements

5.1 Technology Stack

- **Framework**: React.js with TypeScript
- **State Management**: Redux Toolkit or Context API
- **Styling**: Tailwind CSS or styled-components
- **Component Library**: Material UI or Chakra UI

- **Routing**: React Router

5.2 Key Features

1. **Responsive Design**: Mobile-first approach with responsive layouts
2. **Video Player Integration**: Custom YouTube video player with enhanced features
3. **Agent Interaction Interface**: Chat-like interface for communicating with AI agents
4. **Social Features UI**: Components for sharing discoveries and connecting with other users
5. **Agent Customization**: Interface for customizing agent preferences and visual appearance
6. **Shop Interface**: UI for browsing and purchasing visual customizations

5.3 Performance Considerations

- Implement code splitting for faster initial load times
- Use React.lazy and Suspense for component lazy loading
- Implement virtualized lists for handling large datasets
- Optimize image loading with lazy loading and WebP format
- Implement service workers for offline capabilities and caching

6. Backend Requirements

6.1 Technology Stack

- **Primary Language**: Node.js with TypeScript or Python
- **API Framework**: Express.js or FastAPI
- **Database ORM**: Prisma, Sequelize, or SQLAlchemy
- **Task Queue**: Redis with Bull or Celery for background processing
- **WebSockets**: Socket.io or native WebSockets for real-time features

6.2 Key Services

1. **Authentication Service**: Handles user registration, login, and session management
2. **User Service**: Manages user profiles and preferences
3. **Agent Service**: Coordinates AI agent creation, configuration, and interactions
4. **YouTube API Service**: Handles communication with YouTube Data API
5. **Recommendation Service**: Processes user data to generate personalized recommendations
6. **Social Service**: Manages connections between users and shared discoveries
7. **Shop Service**: Handles virtual item purchases and inventory management

6.3 API Endpoints

The backend will expose RESTful API endpoints for the following resources:

- `/api/auth`: Authentication endpoints
- `/api/users`: User management endpoints
- `/api/agents`: AI agent management endpoints
- `/api/videos`: YouTube video data endpoints
- `/api/recommendations`: Video recommendation endpoints
- `/api/social`: Social connection endpoints
- `/api/discoveries`: Shared discoveries endpoints
- `/api/shop`: Virtual shop endpoints

7. API Integration

7.1 YouTube Data API Integration

The application will integrate with the YouTube Data API to access video metadata, captions, and comments.

Key Integration Points:

1. **Authentication**: Implement OAuth 2.0 for server-side web applications
2. **Data Retrieval**:
   - Video metadata via `videos.list` endpoint
   - Captions via `captions.list` and `captions.download` endpoints
   - Comments via `commentThreads.list` endpoint
3. **Quota Management**:
   - Implement caching to reduce API calls
   - Monitor quota usage and implement fallback mechanisms
   - Batch requests when possible

7.2 AI Model Integration

The AI agent service will integrate with language models through their respective APIs:

1. **OpenAI GPT-4**: For sophisticated reasoning and natural language understanding
2. **Anthropic Claude**: As an alternative for certain agent roles
3. **Open-source Models**: For specific tasks where appropriate

8. Social Features Implementation

8.1 Agent-to-Agent Knowledge Sharing

Implement Google's Social Learning framework for agent-to-agent knowledge sharing:

1. **Synthetic Examples**: Agents generate new examples to teach other agents
2. **Synthetic Instructions**: Agents create instructions for specific tasks
3. **Privacy Preservation**: Implement Secret Sharer metric to quantify and prevent data leakage

8.2 User-to-User Social Interactions

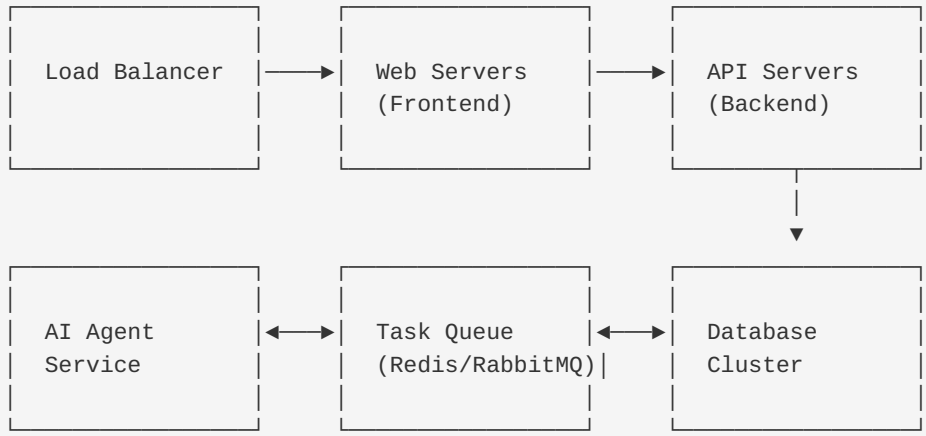
1. **Connection System**: Allow users to connect with others with similar interests
2. **Discovery Sharing**: Enable sharing of agent discoveries with connected users
3. **Collaborative Viewing**: Implement features for synchronized video watching
4. **Activity Feed**: Display recent activities from connected users and their agents

8.3 Collaborative Learning Implementation

```python
# Example implementation of agent-to-agent teaching
def teach_agent(teacher_agent, student_agent, task_description):
    # Generate synthetic examples based on teacher's knowledge
    examples = teacher_agent.generate_synthetic_examples(
        task=task_description,
        num_examples=8,
        diversity_factor=0.7
    )

    # Generate task instructions
    instructions = teacher_agent.generate_instructions(
        task=task_description,
        complexity_level="adaptive",
        format="step_by_step"
    )

    # Transfer knowledge to student agent
    learning_result = student_agent.learn_from_teaching(
        examples=examples,
        instructions=instructions,
        task=task_description
    )

    # Evaluate learning effectiveness
    evaluation_score = evaluate_agent_performance(
        agent=student_agent,
        task=task_description,
        test_cases=generate_test_cases(task_description)
    )

    return {
        "learning_result": learning_result,
        "evaluation_score": evaluation_score
    }
```

9. Deployment and Infrastructure

9.1 Deployment Architecture



9.2 Infrastructure Requirements

1. **Compute Resources**:
   - Web/API Servers: 2-4 vCPUs, 8GB RAM per instance
   - AI Agent Service: 4-8 vCPUs, 16GB RAM per instance
   - Database: 4 vCPUs, 16GB RAM minimum

2. **Storage Requirements**:
   - Database: 100GB+ SSD storage initially, scalable
   - Object Storage: For user uploads and assets

3. **Networking**:
   - Load balancer with SSL termination
   - Internal network for service-to-service communication
   - CDN for static assets

9.3 Scaling Strategy

1. **Horizontal Scaling**: Add more instances of web/API servers based on load
2. **Vertical Scaling**: Increase resources for database and AI services as needed
3. **Database Sharding**: Implement if user data grows significantly
4. **Caching Layer**: Redis for caching frequently accessed data

10. Security Considerations

10.1 Data Protection

1. **Encryption**:
   - Data at rest: Database encryption
   - Data in transit: HTTPS/TLS 1.3
   - Sensitive data: Field-level encryption for PII

2. **Access Control**:
   - Role-based access control (RBAC)
   - Principle of least privilege
   - Regular permission audits

10.2 AI Agent Security

1. **Input Validation**: Sanitize all user inputs to prevent prompt injection
2. **Output Filtering**: Implement content moderation for agent outputs
3. **Rate Limiting**: Prevent abuse of AI agent capabilities
4. **Monitoring**: Track agent behavior for anomalies or misuse

10.3 Compliance Considerations

1. **Privacy Policy**: Clear disclosure of data usage and AI capabilities
2. **Terms of Service**: Define acceptable use of AI agents and social features
3. **GDPR Compliance**: Implement data subject rights (access, deletion, etc.)
4. **COPPA Compliance**: Age verification if targeting users under 13

This technical requirements document provides a comprehensive foundation for building the YouTube companion web app with AI agents and social features. The architecture, frameworks, and implementation details outlined here are designed to create a scalable, secure, and feature-rich application that enhances the YouTube viewing experience through AI assistance and social interaction.