Supermemory 技术架构设计

1. 架构设计

6. 心智模型与知识图谱设计

6.1 目标与作用

- 模拟人类记忆：形成连接、随时间演化、从积累中产生洞察。
- 服务上下文构建：为LLM提供可解释、可控、可追溯的高质量上下文。
- 支撑分析与优化：通过洞察节点输出性能优化、模式识别与策略建议。

6.2 组件与职责

- 知识图谱存储（KG）：持久化节点与边，记录权重、置信度、时间戳与来源。
- 关系引擎（RE）：实体链接、关系识别、路径筛选与合并。
- 演化引擎（EE）：时间衰减、强化、巩固、泛化与冲突解决。
- 洞察生成器（IS）：规则与LLM结合，生成结构化洞察（趋势、异常、建议）。
- 上下文组装器（CA）：沿高分路径抽取片段与概念，按Token预算组装上下文。

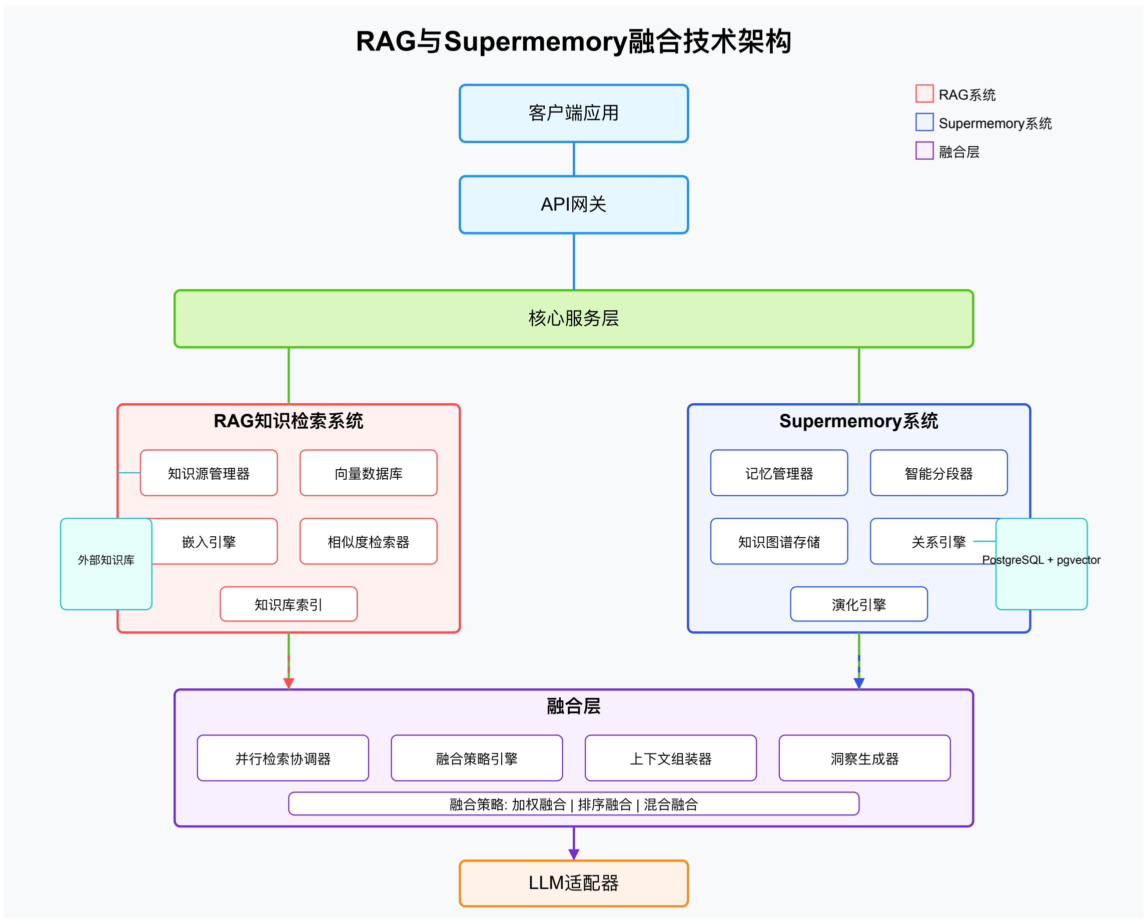
6.3 数据存储选型

- PostgreSQL + pgvector：向量索引与相似度检索，复用现有数据层。
- 图结构实现：使用邻接表（edges表）与必要索引实现图遍历；可选接入Neo4j/JanusGraph用于大规模图。
- 缓存：Redis用于热节点与路径结果缓存，提升检索与推理性能。

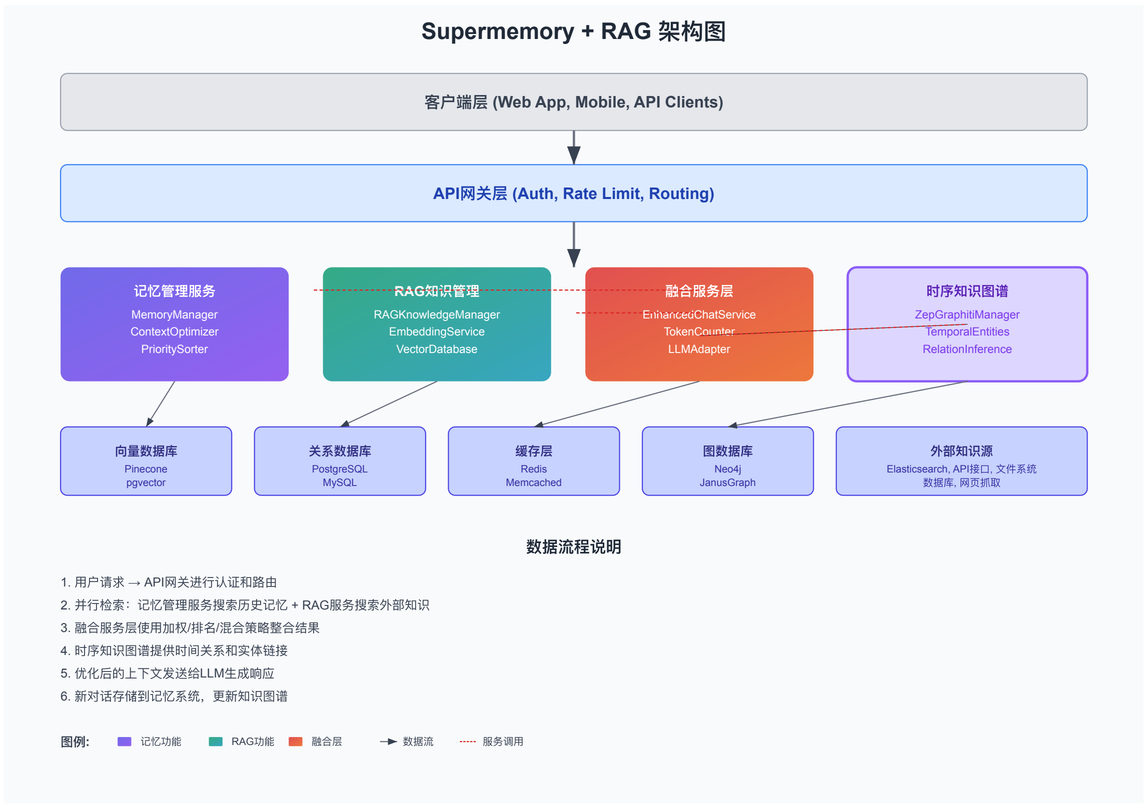
6.4 数据模型

- 节点（nodes）：`id, type, text/attrs, embedding, importance, confidence, created_at, updated_at, provenance`
- 边（edges）：`source, target, type, weight, confidence, created_at, updated_at`
- 类型：`MemoryNode, Entity, Concept, Insight, ConversationTurn`
- 关系：`relates_to, supports, contradicts, causes, precedes, part_of, derived_from`

6.5 摄取与演化流程



6.6 混合检索与路径推理



数据流程说明

1. 用户请求 → API网关进行认证和路由
2. 并行检索：记忆管理服务搜索历史记忆 + RAG服务搜索外部知识
3. 融合服务层使用加权/排名/混合策略整合结果
4. 时序知识图谱提供时间关系和实体链接
5. 优化后的上下文发送给LLM生成响应
6. 新对话存储到记忆系统，更新知识图谱

路径评分维度：`relevance, recency, importance, diversity, relation_type_weights`

6.7 API 扩展

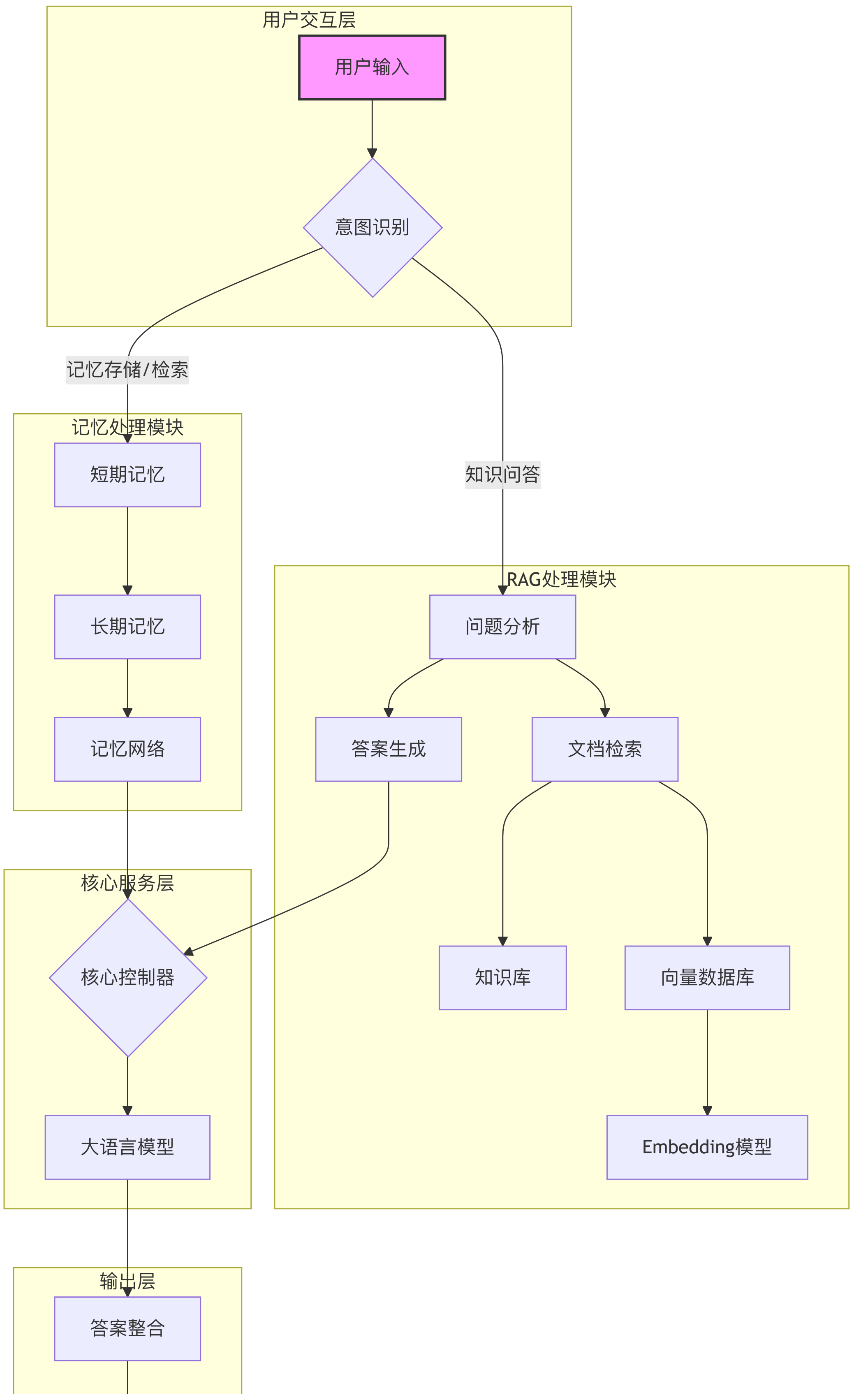
- `GET /v1/memory/graph/nodes?query=...`
- `POST /v1/memory/graph/nodes`
- `POST /v1/memory/graph/edges`
- `POST /v1/memory/graph/link`（自动实体链接与关系识别）
- `GET /v1/memory/graph/traverse`（按条件遍历/路径查询）
- `POST /v1/memory/insights/generate`
- `GET /v1/memory/insights`
- `POST /v1/memory/learn`（强化/反馈更新权重）

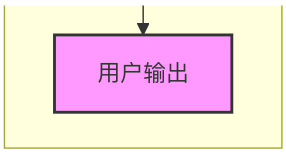
6.8 策略与治理

- 权重与阈值：按项目/用户定制关系类型权重与重要性阈值。
- 生命周期：旧节点衰减与归档、重要节点巩固与版本化。

- 审计与可解释：保留来源、演化记录与评分细节，支撑合规与复盘。

记忆与RAG融合技术架构





2. 技术描述

- **前端**: React@18 + TypeScript + Tailwind CSS + Vite
- **后端**: Node.js + Express@4 + TypeScript
- **数据库**: PostgreSQL + Redis
- **时序知识图谱**: Zep Graphiti Engine + Zep Cloud Service
- **嵌入服务**: Zep内置嵌入服务 + OpenAI text-embedding-3-small (备用)
- **消息队列**: Redis + Bull Queue
- **缓存系统**: Redis (多层缓存策略)
- **监控**: Prometheus + Grafana + Zep Analytics
- **部署**: Docker + Kubernetes

3. 路由定义

路由	用途
/dashboard	管理控制台主页，显示项目概览和使用统计
/projects	项目管理页面，创建和配置AI项目
/proxy-config	代理配置页面，设置LLM模型和记忆策略
/memory	记忆管理页面，查看和管理对话历史
/knowledge-graph	Zep时序知识图谱可视化页面，实体和关系管理
/temporal-entities	时序实体管理页面，实体时间线和演化追踪
/relation-inference	动态关系推理页面，关系发现和强度分析
/memory-synthesis	跨会话记忆合成页面，记忆整合和优化
/segmentation-config	智能分段配置页面，设置分段策略和检索参数
/token-management	Token管理页面，监控使用量和优化策略配置
/analytics	分析仪表板，性能和成本分析
/settings	系统设置页面，账户和安全配置
/api-docs	API文档页面，开发者集成指南

4. API定义

4.1 核心代理API

透明代理接口

```
POST /v1/chat/completions
```

请求参数:

参数名	参数类型	是否必需	描述
model	string	true	LLM模型名称 (gpt-4, claude-3, etc.)
messages	array	true	对话消息数组
temperature	number	false	生成温度 (0-2)
max_tokens	number	false	最大token数
stream	boolean	false	是否流式响应
memory_config	object	false	记忆配置参数

响应:

参数名	参数类型	描述
id	string	请求唯一标识
object	string	响应对象类型
created	number	创建时间戳
model	string	使用的模型
choices	array	生成的回复选项
usage	object	Token使用统计
memory_info	object	记忆处理信息

示例请求:

```json
{
  "model": "gpt-4",
  "messages": [
    {"role": "user", "content": "你好，我想了解AI的发展历史"}
  ],
  "temperature": 0.7,
  "memory_config": {
    "enable_memory": true,
    "memory_depth": 10,
    "relevance_threshold": 0.8
  }
}
```

记忆管理API

```
GET /v1/memory/conversations
POST /v1/memory/clear
PUT /v1/memory/update
GET /v1/memory/search
POST /v1/memory/retrieve
```

智能分段配置API

```
GET /v1/segmentation/config
PUT /v1/segmentation/config
POST /v1/segmentation/test
GET /v1/segmentation/performance
```

Token管理API

```
GET /v1/token/usage
GET /v1/token/statistics
PUT /v1/token/config
POST /v1/token/optimize
```

项目管理API

```
GET /v1/projects
POST /v1/projects
PUT /v1/projects/{id}
DELETE /v1/projects/{id}
```

Zep Graphiti时序知识图谱API

```
GET /v1/zep-graphiti/entities
POST /v1/zep-graphiti/entities
GET /v1/zep-graphiti/entities/{entityId}/timeline
GET /v1/zep-graphiti/relations
POST /v1/zep-graphiti/relations/infer
GET /v1/zep-graphiti/graph/traverse
POST /v1/zep-graphiti/memories/synthesize
POST /v1/zep-graphiti/deduplication
GET /v1/zep-graphiti/optimization/suggestions
GET /v1/zep-graphiti/health
```

5. 服务器架构图

```
graph TD
    A[负载均衡器] --> B[API网关集群]
    B --> C[认证服务]
    B --> D[代理服务集群]

    D --> E[Zep Graphiti时序知识图谱服务]
    D --> F[上下文处理服务]
    D --> G[LLM调用服务]

    E --> H[Zep Cloud服务]
    E --> I[时序实体管理器]
    E --> J[动态关系推理引擎]
    E --> K[跨会话记忆合成器]
    E --> L[智能去重引擎]
    E --> M[时序感知优化器]

    F --> N[缓存集群]
    G --> O[LLM提供商集群]

    H --> P[Graphiti引擎]
    H --> Q[时序数据存储]

    D --> R[异步任务队列]
    R --> S[记忆更新服务]
    S --> T[数据库集群]

    subgraph "入口层"
        A
        B
    end

    subgraph "服务层"
        C
        D
        E
        F
        G
        S
    end

    subgraph "Zep Graphiti层"
        I
        J
        K
        L
        M
        H
        P
        Q
    end

    subgraph "数据层"
        N
        T
    end

    subgraph "队列层"
        R
    end
```

6. 数据模型

6.1 数据模型定义

```
erDiagram
    USER ||--o{ PROJECT : owns
    PROJECT ||--o{ CONVERSATION : contains
    CONVERSATION ||--o{ MESSAGE : includes
    MESSAGE ||--o{ TEMPORAL_ENTITY : generates
    PROJECT ||--o{ API_KEY : has
    PROJECT ||--o{ SEGMENTATION_CONFIG : configures
    PROJECT ||--o{ TOKEN_CONFIG : configures
    USER ||--o{ USAGE_LOG : generates
    USER ||--o{ TOKEN_USAGE_LOG : generates
    TEMPORAL_ENTITY ||--o{ TEMPORAL_RELATION : source
    TEMPORAL_ENTITY ||--o{ TEMPORAL_RELATION : target
    TEMPORAL_ENTITY ||--o{ ENTITY_TIMELINE : tracks
    TEMPORAL_RELATION ||--o{ RELATION_TIMELINE : tracks
    PROJECT ||--o{ GRAPHITI_GRAPH : contains

    USER {
        uuid id PK
        string email
        string password_hash
        string name
        string plan
        timestamp created_at
        timestamp updated_at
    }
}
```

```
PROJECT {
    uuid id PK
    uuid user_id FK
    string name
    string description
    json config
    string status
    timestamp created_at
    timestamp updated_at
}

CONVERSATION {
    uuid id PK
    uuid project_id FK
    string session_id
    json metadata
    timestamp created_at
    timestamp updated_at
}

MESSAGE {
    uuid id PK
    uuid conversation_id FK
    string role
    text content
    json metadata
    integer token_count
    timestamp created_at
}

TEMPORAL_ENTITY {
    uuid id PK
    uuid message_id FK
    string entity_id
    string entity_type
    json properties
    json temporal_context
    json metadata
    timestamp created_at
    timestamp last_updated
    timestamp valid_from
    timestamp valid_to
}

TEMPORAL_RELATION {
    }

        uuid id PK
        string relation_id
        uuid source_entity_id FK
        uuid target_entity_id FK
        string relation_type
        float strength
        json properties
        json temporal_context
        json metadata
        timestamp created_at
        timestamp last_updated
        timestamp valid_from
        timestamp valid_to
    }

    ENTITY_TIMELINE {
        uuid id PK
        uuid entity_id FK
        string event_type
        json changes
        json context
        timestamp event_timestamp
        timestamp created_at
    }

    RELATION_TIMELINE {
        uuid id PK
        uuid relation_id FK
        string event_type
        json changes
        json context
        timestamp event_timestamp
        timestamp created_at
    }

    GRAPHITI_GRAPH {
        uuid id PK
        uuid project_id FK
        string graph_id
        json graph_metadata
        json temporal_constraints
        integer entity_count
        integer relation_count
        timestamp created_at
        timestamp last_updated
    }
```

```
SEGMENTATION_CONFIG {
    uuid id PK
    uuid project_id FK
    integer max_chunk_size
    integer overlap_size
    string segmentation_strategy
    json embedding_config
    float similarity_threshold
    json weights_config
    timestamp created_at
    timestamp updated_at
}

TOKEN_CONFIG {
    uuid id PK
    uuid project_id FK
    integer max_context_tokens
    integer reserved_tokens
    json compression_config
    json priority_weights
    boolean auto_optimization
    timestamp created_at
    timestamp updated_at
}

TOKEN_USAGE_LOG {
    uuid id PK
    uuid user_id FK
    uuid project_id FK
    uuid conversation_id FK
    integer input_tokens
    integer output_tokens
    integer memory_tokens
    integer compressed_tokens
    float compression_ratio
    string optimization_strategy
    timestamp created_at
}

API_KEY {
    uuid id PK
    uuid project_id FK
    string key_hash
    string name
    json permissions
```

```
        timestamp expires_at
        timestamp created_at
    }

    USAGE_LOG {
        uuid id PK
        uuid user_id FK
        uuid project_id FK
        string endpoint
        integer tokens_used
        float cost
        timestamp created_at
    }
```

6.2 数据定义语言

用户表 (users)

```
-- 创建用户表
CREATE TABLE users (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    email VARCHAR(255) UNIQUE NOT NULL,
    password_hash VARCHAR(255) NOT NULL,
    name VARCHAR(100) NOT NULL,
    plan VARCHAR(20) DEFAULT 'free' CHECK (plan IN ('free', 'pro',
'enterprise')),
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_users_email ON users(email);
CREATE INDEX idx_users_plan ON users(plan);
```

项目表 (projects)

```
-- 创建项目表
CREATE TABLE projects (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    user_id UUID NOT NULL REFERENCES users(id) ON DELETE CASCADE,
    name VARCHAR(100) NOT NULL,
    description TEXT,
    config JSONB DEFAULT '{}',
    status VARCHAR(20) DEFAULT 'active' CHECK (status IN ('active',
'paused', 'deleted')),
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
```

```sql
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_projects_user_id ON projects(user_id);
CREATE INDEX idx_projects_status ON projects(status);
```

对话表 (conversations)

```sql
-- 创建对话表
CREATE TABLE conversations (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    project_id UUID NOT NULL REFERENCES projects(id) ON DELETE CASCADE,
    session_id VARCHAR(255) NOT NULL,
    metadata JSONB DEFAULT '{}',
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_conversations_project_id ON conversations(project_id);
CREATE INDEX idx_conversations_session_id ON conversations(session_id);
CREATE INDEX idx_conversations_created_at ON conversations(created_at
DESC);
```

消息表 (messages)

```sql
-- 创建消息表
CREATE TABLE messages (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    conversation_id UUID NOT NULL REFERENCES conversations(id) ON DELETE
CASCADE,
    role VARCHAR(20) NOT NULL CHECK (role IN ('user', 'assistant',
'system')),
    content TEXT NOT NULL,
    metadata JSONB DEFAULT '{}',
    token_count INTEGER DEFAULT 0,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_messages_conversation_id ON messages(conversation_id);
CREATE INDEX idx_messages_created_at ON messages(created_at DESC);
CREATE INDEX idx_messages_token_count ON messages(token_count);
```

记忆块表 (memory_chunks)

```sql
-- 创建记忆块表
CREATE TABLE memory_chunks (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    message_id UUID NOT NULL REFERENCES messages(id) ON DELETE CASCADE,
    content TEXT NOT NULL,
    embedding VECTOR(1536), -- 使用pgvector扩展
    relevance_score FLOAT DEFAULT 0.0,
    chunk_type VARCHAR(50) DEFAULT 'semantic' CHECK (chunk_type IN
('semantic', 'paragraph', 'fixed', 'sliding')),
    chunk_index INTEGER DEFAULT 0,
    metadata JSONB DEFAULT '{}',
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建向量索引
CREATE INDEX idx_memory_chunks_embedding ON memory_chunks USING ivfflat
(embedding vector_cosine_ops);
CREATE INDEX idx_memory_chunks_message_id ON memory_chunks(message_id);
CREATE INDEX idx_memory_chunks_relevance_score ON
memory_chunks(relevance_score DESC);
CREATE INDEX idx_memory_chunks_chunk_type ON memory_chunks(chunk_type);
CREATE INDEX idx_memory_chunks_chunk_index ON memory_chunks(chunk_index);
```

分段配置表 (segmentation_configs)

```sql
-- 创建分段配置表
CREATE TABLE segmentation_configs (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    project_id UUID NOT NULL REFERENCES projects(id) ON DELETE CASCADE,
    max_chunk_size INTEGER DEFAULT 512,
    overlap_size INTEGER DEFAULT 50,
    segmentation_strategy VARCHAR(50) DEFAULT 'semantic' CHECK
(segmentation_strategy IN ('semantic', 'paragraph', 'fixed', 'sliding',
'hybrid')),
    embedding_config JSONB DEFAULT '{"model": "text-embedding-3-small",
"dimensions": 1536}',
    similarity_threshold FLOAT DEFAULT 0.7,
    weights_config JSONB DEFAULT '{"semantic": 0.4, "temporal": 0.3,
"importance": 0.2, "position": 0.1}',
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_segmentation_configs_project_id ON
```

```
segmentation_configs(project_id);
CREATE UNIQUE INDEX idx_segmentation_configs_project_unique ON
segmentation_configs(project_id);
```

Token配置表 (token_configs)

```
-- 创建Token配置表
CREATE TABLE token_configs (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    project_id UUID NOT NULL REFERENCES projects(id) ON DELETE CASCADE,
    max_context_tokens INTEGER DEFAULT 4096,
    reserved_tokens INTEGER DEFAULT 1000,
    compression_config JSONB DEFAULT '{"enable_compression": true,
"compression_ratio": 0.7, "summary_model": "gpt-3.5-turbo"}',
    priority_weights JSONB DEFAULT '{"temporal": 0.3, "relevance": 0.4,
"importance": 0.2, "user_preference": 0.1}',
    auto_optimization BOOLEAN DEFAULT true,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_token_configs_project_id ON token_configs(project_id);
CREATE UNIQUE INDEX idx_token_configs_project_unique ON
token_configs(project_id);
```

Token使用日志表 (token_usage_logs)

```
-- 创建Token使用日志表
CREATE TABLE token_usage_logs (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    user_id UUID NOT NULL REFERENCES users(id) ON DELETE CASCADE,
    project_id UUID REFERENCES projects(id) ON DELETE SET NULL,
    conversation_id UUID REFERENCES conversations(id) ON DELETE SET NULL,
    input_tokens INTEGER DEFAULT 0,
    output_tokens INTEGER DEFAULT 0,
    memory_tokens INTEGER DEFAULT 0,
    compressed_tokens INTEGER DEFAULT 0,
    compression_ratio FLOAT DEFAULT 1.0,
    optimization_strategy VARCHAR(100),
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_token_usage_logs_user_id ON token_usage_logs(user_id);
CREATE INDEX idx_token_usage_logs_project_id ON
```

```sql
token_usage_logs(project_id);
CREATE INDEX idx_token_usage_logs_conversation_id ON
token_usage_logs(conversation_id);
CREATE INDEX idx_token_usage_logs_created_at ON token_usage_logs(created_at
DESC);

-- 创建分区表（按月分区）
CREATE TABLE token_usage_logs_y2024m01 PARTITION OF token_usage_logs
FOR VALUES FROM ('2024-01-01') TO ('2024-02-01');
```

API密钥表 (api_keys)

```sql
-- 创建API密钥表
CREATE TABLE api_keys (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    project_id UUID NOT NULL REFERENCES projects(id) ON DELETE CASCADE,
    key_hash VARCHAR(255) NOT NULL UNIQUE,
    name VARCHAR(100) NOT NULL,
    permissions JSONB DEFAULT '{}',
    expires_at TIMESTAMP WITH TIME ZONE,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_api_keys_project_id ON api_keys(project_id);
CREATE INDEX idx_api_keys_key_hash ON api_keys(key_hash);
```

使用日志表 (usage_logs)

```sql
-- 创建使用日志表
CREATE TABLE usage_logs (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    user_id UUID NOT NULL REFERENCES users(id) ON DELETE CASCADE,
    project_id UUID REFERENCES projects(id) ON DELETE SET NULL,
    endpoint VARCHAR(255) NOT NULL,
    tokens_used INTEGER DEFAULT 0,
    cost DECIMAL(10,6) DEFAULT 0.0,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- 创建索引
CREATE INDEX idx_usage_logs_user_id ON usage_logs(user_id);
CREATE INDEX idx_usage_logs_project_id ON usage_logs(project_id);
CREATE INDEX idx_usage_logs_created_at ON usage_logs(created_at DESC);

-- 创建分区表（按月分区）
```

```sql
CREATE TABLE usage_logs_y2024m01 PARTITION OF usage_logs
FOR VALUES FROM ('2024-01-01') TO ('2024-02-01');
```

初始化数据

```sql
-- 插入示例用户
INSERT INTO users (email, password_hash, name, plan) VALUES
('admin@supermemory.ai', '$2b$10$example_hash', 'Admin User',
'enterprise'),
('demo@example.com', '$2b$10$example_hash', 'Demo User', 'pro');

-- 插入示例项目
INSERT INTO projects (user_id, name, description, config) VALUES
((SELECT id FROM users WHERE email = 'demo@example.com'),
 'Demo Chat Bot',
 'A demonstration chatbot with memory capabilities',
 '{"model": "gpt-4", "memory_depth": 10, "temperature": 0.7}');

-- 插入默认分段配置
INSERT INTO segmentation_configs (project_id, max_chunk_size, overlap_size,
segmentation_strategy, similarity_threshold) VALUES
((SELECT id FROM projects WHERE name = 'Demo Chat Bot'),
 512, 50, 'semantic', 0.7);

-- 插入默认Token配置
INSERT INTO token_configs (project_id, max_context_tokens, reserved_tokens,
auto_optimization) VALUES
((SELECT id FROM projects WHERE name = 'Demo Chat Bot'),
 4096, 1000, true);

-- 插入示例API密钥
INSERT INTO api_keys (project_id, key_hash, name, permissions) VALUES
((SELECT id FROM projects WHERE name = 'Demo Chat Bot'),
 '$2b$10$demo_api_key_hash',
 'Demo API Key',
 '{"read": true, "write": true, "admin": false}');
```