BAKAME AI - Visual Architecture Diagrams

🖼 System Architecture Diagram

```
graph TB
    subgraph "User Layer"
        U1[Feature Phone Users<br/>Voice Calls]
        U2[Feature Phone Users<br/>SMS Messages]
        U3[Web Admin Users<br/>Dashboard]
    end

    subgraph "Communication Layer"
        T1[Twilio Voice API]
        T2[Twilio SMS API]
        W1[Web Interface]
    end

    subgraph "API Gateway"
        F1[FastAPI Backend<br/>app-pyzfduqr.fly.dev]
    end

    subgraph "Learning Modules"
        M1[English Module<br/>Grammar, Pronunciation]
        M2[Math Module<br/>Mental Math, RWF Context]
        M3[Comprehension Module<br/>Stories, Q&A]
        M4[Debate Module<br/>Critical Thinking]
        M5[General Module<br/>Entry Point, Routing]
    end

    subgraph "AI Processing"
        A1[OpenAI GPT-4o-mini<br/>Text Generation]
        A2[OpenAI Whisper<br/>Speech-to-Text]
        A3[Llama LLM<br/>Alternative AI]
        A4[Deepgram<br/>Alternative STT]
    end

    subgraph "Data Layer"
        D1[PostgreSQL<br/>User Data, Sessions]
        D2[Redis<br/>Session Management]
        D3[File System<br/>Audio, Logs]
    end

    subgraph "Advanced Services"
        S1[Emotional Intelligence]
        S2[Gamification Engine]
        S3[Predictive Analytics]
        S4[Community Features]
        S5[Teacher Dashboard]
    end

    U1 --> T1
    U2 --> T2
    U3 --> W1

    T1 --> F1
    T2 --> F1
    W1 --> F1

    F1 --> M1
    F1 --> M2
    F1 --> M3
    F1 --> M4
```

```
F1 --> M5

M1 --> A1
M2 --> A1
M3 --> A1
M4 --> A1
M5 --> A1

F1 --> A2
F1 --> A3
F1 --> A4

F1 --> D1
F1 --> D2
F1 --> D3

F1 --> S1
F1 --> S2
F1 --> S3
F1 --> S4
F1 --> S5

style U1 fill:#e1f5fe
style U2 fill:#e1f5fe
style U3 fill:#e1f5fe
style F1 fill:#f3e5f5
style A1 fill:#fff3e0
style A2 fill:#fff3e0
style D1 fill:#e8f5e8
style D2 fill:#e8f5e8
```

♻ Data Flow Architecture

```
sequenceDiagram
    participant User as Feature Phone User
    participant Twilio as Twilio API
    participant API as FastAPI Backend
    participant Redis as Redis Cache
    participant AI as OpenAI/Llama
    participant DB as PostgreSQL
    participant Module as Learning Module

    User->>Twilio: Voice Call/SMS
    Twilio->>API: Webhook Request
    API->>Redis: Get User Context
    Redis-->>API: User Session Data

    alt Voice Call
        API->>AI: Transcribe Audio (Whisper)
        AI-->>API: Text Input
    end

    API->>Module: Process Learning Input
    Module->>AI: Generate Educational Response
    AI-->>Module: AI Response
    Module-->>API: Formatted Response

    API->>Redis: Update Session Context
    API->>DB: Log Interaction
    API->>Twilio: TwiML Response
    Twilio->>User: Voice/SMS Response
```

♟ Learning Module Flow

```
flowchart TD
```

```
A[User Input] --> B{Input Type?}
B -->|Voice| C[Whisper STT]
B -->|SMS| D[Direct Text]

C --> E[Text Processing]
D --> E

E --> F{Module Detection}
F -->|english| G[English Module]
F -->|math| H[Math Module]
F -->|comprehension| I[Comprehension Module]
F -->|debate| J[Debate Module]
F -->|general| K[General Module]

G --> L[Grammar/Pronunciation Processing]
H --> M[Math Problem Generation]
I --> N[Story Generation/Analysis]
J --> O[Debate Topic Processing]
K --> P[General Q&A/Routing]

L --> Q[AI Response Generation]
M --> Q
N --> Q
O --> Q
P --> Q

Q --> R[Cultural Context Integration]
R --> S[Emotional Intelligence]
S --> T[Gamification Updates]
T --> U[Response Formatting]

U --> V{Output Type?}
V -->|Voice| W[TwiML Voice Response]
V -->|SMS| X[TwiML SMS Response]

W --> Y[User Receives Audio]
X --> Z[User Receives Text]

style A fill:#e3f2fd
style Q fill:#fff3e0
style R fill:#f1f8e9
style S fill:#fce4ec
style T fill:#e8eaf6
```

🧠 AI Processing Pipeline

```
graph LR
    subgraph "Input Processing"
        I1[Voice Input] --> STT[Speech-to-Text<br/>Whisper/Deepgram]
        I2[SMS Input] --> TXT[Text Input]
        STT --> TXT
    end

    subgraph "Context Management"
        TXT --> CTX[Context Retrieval<br/>Redis Session]
        CTX --> HIST[Conversation History]
        CTX --> STATE[User State]
    end

    subgraph "Module Processing"
        HIST --> MOD[Module Selection<br/>English/Math/etc.]
        STATE --> MOD
        MOD --> LOGIC[Module Logic<br/>Educational Processing]
    end

    subgraph "AI Generation"
```

```
        LOGIC --> PROMPT[Prompt Engineering<br/>Cultural Context]
        PROMPT --> LLM[LLM Processing<br/>GPT-4o-mini/Llama]
        LLM --> RESP[AI Response]
    end

    subgraph "Enhancement Services"
        RESP --> EMO[Emotional Intelligence<br/>Mood Detection]
        EMO --> GAM[Gamification<br/>Points/Achievements]
        GAM --> CULT[Cultural Adaptation<br/>Kinyarwanda Integration]
    end

    subgraph "Output Generation"
        CULT --> FMT[Response Formatting]
        FMT --> VOICE[TwiML Voice]
        FMT --> SMS[TwiML SMS]
    end

    style STT fill:#ffecb3
    style LLM fill:#ffecb3
    style EMO fill:#f8bbd9
    style GAM fill:#c8e6c9
    style CULT fill:#dcedc8
```

▥ Database Schema Visualization

```
erDiagram
    USERS {
        int id PK
        string phone_number UK
        string user_type
        string name
        string region
        string school
        string grade_level
        boolean is_active
        datetime created_at
        datetime last_active
        int total_points
        string current_level
    }

    USER_SESSIONS {
        int id PK
        string phone_number FK
        string session_id
        string module_name
        string interaction_type
        text user_input
        text ai_response
        datetime timestamp
        float session_duration
    }

    MODULE_USAGE {
        int id PK
        string phone_number FK
        string module_name
        int usage_count
        datetime last_used
        float total_duration
    }

    LEARNING_GROUPS {
        int id PK
        string name
        text description
```

```
        string group_type
        string region
        string school
        string grade_level
        string subject
        string teacher_phone FK
        boolean is_active
        datetime created_at
        int max_members
    }

    GROUP_MEMBERSHIPS {
        int id PK
        int group_id FK
        string user_phone FK
        string role
        datetime joined_at
        boolean is_active
    }

    PEER_CONNECTIONS {
        int id PK
        string user1_phone FK
        string user2_phone FK
        string connection_type
        string status
        datetime created_at
        datetime last_interaction
    }

    PEER_LEARNING_SESSIONS {
        int id PK
        string session_id UK
        int group_id FK
        int connection_id FK
        string module_name
        string topic
        text participants
        datetime started_at
        datetime ended_at
        text session_summary
    }

    WEB_USERS {
        int id PK
        string email UK
        string full_name
        string hashed_password
        string role
        string organization
        boolean is_active
        datetime created_at
    }

    USERS ||--o{ USER_SESSIONS : "has sessions"
    USERS ||--o{ MODULE_USAGE : "uses modules"
    USERS ||--o{ GROUP_MEMBERSHIPS : "joins groups"
    USERS ||--o{ PEER_CONNECTIONS : "connects with"
    LEARNING_GROUPS ||--o{ GROUP_MEMBERSHIPS : "contains members"
    LEARNING_GROUPS ||--o{ PEER_LEARNING_SESSIONS : "hosts sessions"
    PEER_CONNECTIONS ||--o{ PEER_LEARNING_SESSIONS : "enables sessions"
```

🌐 Deployment Architecture

```
graph TB
    subgraph "External Services"
```

```
        EXT1[Twilio<br/>Voice/SMS API]
        EXT2[OpenAI<br/>GPT + Whisper]
        EXT3[Llama API<br/>Alternative LLM]
        EXT4[NewsAPI<br/>Current Events]
        EXT5[Deepgram<br/>Alternative STT]
    end

    subgraph "Cloud Infrastructure"
        subgraph "Fly.io Platform"
            APP[FastAPI Backend<br/>app-pyzfduqr.fly.dev]
            DB[PostgreSQL<br/>Database]
        end

        subgraph "Devin Apps Platform"
            ADMIN[Admin Dashboard<br/>project-handling-app-jiwikt4q.devinapps.com]
        end

        subgraph "Redis Cloud"
            REDIS[Redis Cache<br/>Session Management]
        end
    end

    subgraph "User Access Points"
        PHONE[Feature Phones<br/>Voice/SMS]
        WEB[Web Browsers<br/>Admin Interface]
    end

    PHONE --> EXT1
    EXT1 --> APP
    WEB --> ADMIN
    ADMIN --> APP

    APP --> DB
    APP --> REDIS
    APP --> EXT2
    APP --> EXT3
    APP --> EXT4
    APP --> EXT5

    style APP fill:#e1f5fe
    style ADMIN fill:#f3e5f5
    style DB fill:#e8f5e8
    style REDIS fill:#ffecb3
    style EXT1 fill:#fff3e0
    style EXT2 fill:#fff3e0
```

🎮 Gamification System Architecture

```
mindmap
  root((Gamification Engine))
    Achievement System
      Ubuntu Spirit
        Community values
        Helping others
      Hill Climber
        Overcoming challenges
        Persistence
      Knowledge Seeker
        Learning streaks
        Curiosity
      Unity Builder
        Respectful debate
        Collaboration
      Subject Masters
        Math Champion
        Story Master
```

```
      English Explorer
      Resilience Warrior

  Progress Tracking
    Point System
      Module completion
      Correct answers
      Engagement time
    Level Progression
      Beginner
      Learner
      Achiever
      Expert
      Master
    Difficulty Adaptation
      Performance-based
      Automatic scaling
      Cultural context

  Cultural Integration
    Rwanda Context
      RWF calculations
      Local geography
      Community values
    Kinyarwanda Phrases
      Motivational messages
      Cultural greetings
      Success celebrations
    Ubuntu Philosophy
      Community support
      Shared learning
      Collective growth
```

🔒 Security Architecture

```
graph TD
    subgraph "User Authentication"
        A1[Phone-Based Identity<br/>No Registration Required]
        A2[Web Admin Authentication<br/>JWT + Role-Based Access]
    end

    subgraph "Data Protection"
        B1[HTTPS/TLS Encryption<br/>All Communications]
        B2[Database Encryption<br/>Sensitive Data Protection]
        B3[Session TTL Management<br/>Automatic Cleanup]
    end

    subgraph "Access Control"
        C1[Role-Based Permissions<br/>Admin/Super Admin]
        C2[Organization Isolation<br/>Multi-Tenant Support]
        C3[API Rate Limiting<br/>Abuse Prevention]
    end

    subgraph "Privacy Compliance"
        D1[Data Minimization<br/>Only Necessary Data]
        D2[User Consent<br/>Transparent Processing]
        D3[Data Export/Deletion<br/>User Rights]
    end

    A1 --> B1
    A2 --> B1
    B1 --> C1
    B2 --> C2
    B3 --> C3
    C1 --> D1
    C2 --> D2
```

```
    C3 --> D3

    style A1 fill:#e3f2fd
    style A2 fill:#e3f2fd
    style B1 fill:#f1f8e9
    style B2 fill:#f1f8e9
    style B3 fill:#f1f8e9
    style C1 fill:#fff3e0
    style C2 fill:#fff3e0
    style C3 fill:#fff3e0
    style D1 fill:#fce4ec
    style D2 fill:#fce4ec
    style D3 fill:#fce4ec
```

📊 Analytics & Monitoring Flow

```
graph LR
    subgraph "Data Collection"
        DC1[User Interactions<br/>Voice/SMS Logs]
        DC2[Module Usage<br/>Learning Analytics]
        DC3[Performance Metrics<br/>Response Times]
        DC4[Error Tracking<br/>System Health]
    end

    subgraph "Processing"
        P1[Real-time Analytics<br/>Live Dashboard]
        P2[Batch Processing<br/>Historical Analysis]
        P3[Predictive Models<br/>Learning Patterns]
    end

    subgraph "Storage"
        S1[PostgreSQL<br/>Structured Data]
        S2[Redis<br/>Real-time Cache]
        S3[File System<br/>Logs & Audio]
    end

    subgraph "Visualization"
        V1[Admin Dashboard<br/>Usage Statistics]
        V2[Teacher Portal<br/>Student Progress]
        V3[Export Tools<br/>CSV Reports]
    end

    DC1 --> P1
    DC2 --> P2
    DC3 --> P1
    DC4 --> P1

    P1 --> S2
    P2 --> S1
    P3 --> S1

    S1 --> V1
    S2 --> V1
    S1 --> V2
    S1 --> V3

    style DC1 fill:#e3f2fd
    style DC2 fill:#e3f2fd
    style P1 fill:#fff3e0
    style P2 fill:#fff3e0
    style P3 fill:#fff3e0
    style V1 fill:#f1f8e9
    style V2 fill:#f1f8e9
    style V3 fill:#f1f8e9
```

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Status: Complete Architecture Visualization
Tools: Mermaid.js for dynamic diagrams