

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[ElevenLabs ConvAI<br/>Voice Processing]
        A2[OpenAI GPT-4o-mini<br/>Text Generation]
        A3[OpenAI Whisper<br/>Speech-to-Text]
        A4[Llama LLM<br/>Alternative AI]
        A5[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 (ElevenLabs/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[ElevenLabs ConvAI/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[ElevenLabs<br/>ConvAI Agent]
  EXT2B[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:#ffe0b2
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
```

Diagram Version: 1.0

Last Updated: September 6, 2025

Status: Complete Architecture Visualization

Tools: Mermaid.js for dynamic diagrams