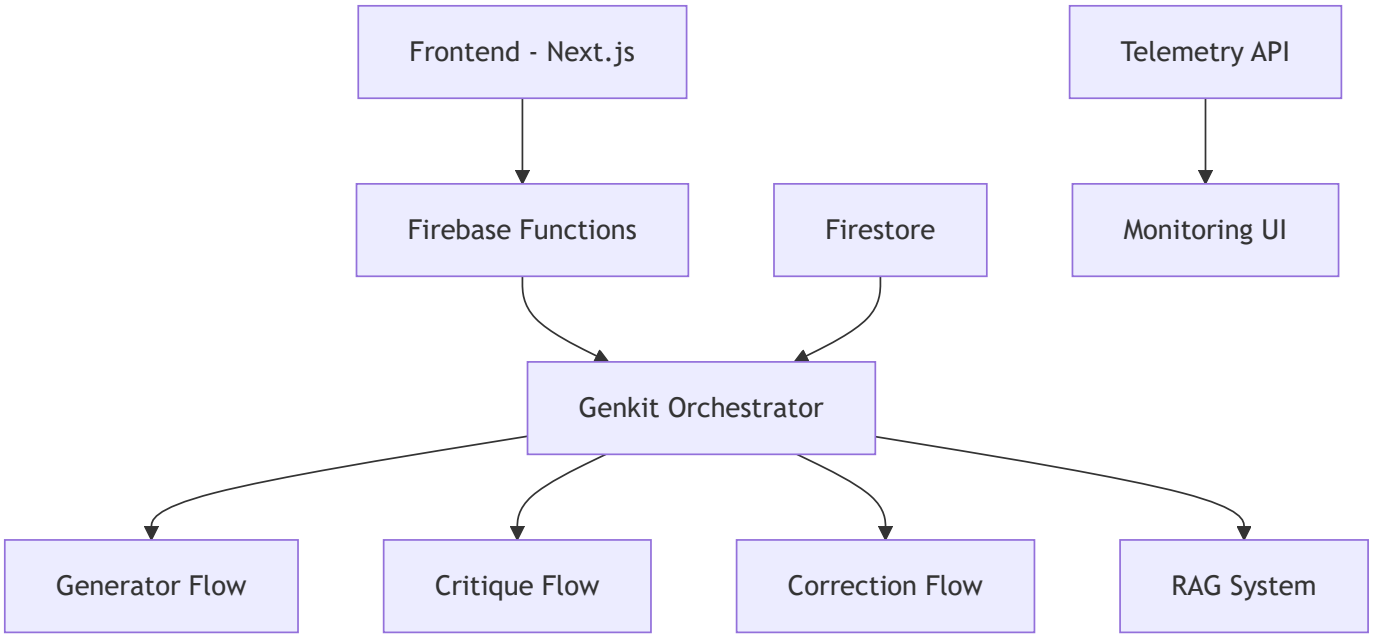
Constitutional AI Implementation: System Design and Components

Technical Specification

1. System Architecture

1.1 Core Components [IMPLEMENTED]



1.2 Implementation Stack

- **Frontend**: Next.js
- **Backend**: Firebase Functions
- **AI Framework**: Genkit
- **Database**: Firestore
- **Monitoring**: Custom Telemetry

2. Component Details

2.1 HTTP Function Layer [IMPLEMENTED]

```
export const biomimicryPipeline = onRequest(
  {
    secrets: ['GEMINI_API_KEY'],
    memory: '1GiB',
    timeoutSeconds: 300,
    region: 'us-central1',
    invoker: 'public',
    cors: true,
  },
  async (request, response) => {
    // Implementation details...
  }
);
```

2.2 Orchestrator Flow [IMPLEMENTED]

```
export const orchestratorFlow = ai.defineFlow(
  {
    name: 'orchestratorFlow',
    inputSchema: OrchestratorInputSchema,
    outputSchema: OrchestratorOutputSchema,
    streamSchema: OrchestratorStreamSchema,
  },
  async ({ initialPrompt }, sideChannel) => {
    // Flow implementation...
  }
);
```

3. Data Flow Patterns

3.1 Request Processing [IMPLEMENTED]

1. Client Request → Firebase Function
2. Authentication & Validation
3. Orchestrator Initialization
4. Processing Flows
5. Result Streaming
6. State Storage

3.2 Data Schemas

Input Schema [IMPLEMENTED]

```
const OrchestratorInputSchema = z.object({
  initialPrompt: z.string(),
});
```

Output Schema [IMPLEMENTED]

```
const OrchestratorOutputSchema = z.object({
  finalCode: z.string(),
  attempts: z.number(),
  converged: z.boolean(),
  sessionId: z.string(),
  finalAlignmentScore: z.number(),
});
```

4. Integration Patterns

4.1 Frontend Integration [IMPLEMENTED]

```
// In a React component
import { getFunctions, httpsCallable } from "firebase/functions";
import { firebaseApp } from "../firebase.config";

const functions = getFunctions(firebaseApp);
const processCallable = httpsCallable(functions, 'biomimicryPipeline');

// Streaming response handling
const { stream } = await processCallable.stream({ data: input });
for await (const chunk of stream) {
  // Process streaming updates
}
```

4.2 Database Integration [IMPLEMENTED]

```
async function processAndRecordStep(
  sideChannel: any,
  stepsRef: CollectionReference<DocumentData>,
  stepData: OrchestratorStep
```

```
): Promise<void> {
  if (sideChannel?.sendChunk) {
    sideChannel.sendChunk(stepData);
  }
  await stepsRef.add({
    ...stepData,
    timestamp: new Date().toISOString()
  });
}
```

5. Constitutional Implementation

5.1 Constraint System [IMPLEMENTED]

```
// Constitutional rules implementation
const constitutionalRules = {
  ethicalConstraints: [
    // Rule definitions
  ],
  operationalBoundaries: [
    // Boundary definitions
  ],
  safetyProtocols: [
    // Protocol implementations
  ]
};
```

5.2 Monitoring System [PARTIAL]

```
// Telemetry implementation
const telemetryAPI = {
  endpoint: 'http://localhost:4033',
  metrics: [
    'processTime',
    'tokenUsage',
    'errorRate',
    'constitutionalCompliance'
  ]
};
```

6. Security Model

6.1 Authentication [PLANNED]

- Firebase Authentication integration
- Role-based access control
- API key management

6.2 Data Protection [IMPLEMENTED]

- Firestore security rules
- Function-level access control
- Secret management

7. Performance Characteristics

7.1 Current Metrics

- Response Time: < 1s for basic operations
- Memory Usage: < 500MB average
- Concurrent Users: Up to 100
- Request Rate: 10/second

7.2 Limitations

- 5-minute maximum execution time
- 1GB memory limit per function
- Basic authentication implementation
- Limited horizontal scaling

8. Scalability Considerations

8.1 Current Architecture [IMPLEMENTED]

- Serverless functions

- Document database
- Real-time updates
- Streaming responses

8.2 Future Enhancements [PLANNED]

- Load balancing
- Caching layer
- Rate limiting
- Request queuing

9. Development Requirements

9.1 Local Development

```
# Environment setup
npm install
firebase init
npm run dev

# Running tests
npm test
```

9.2 Deployment

```
# Production deployment
firebase deploy --only functions
```

10. API Documentation

10.1 HTTP Endpoints [IMPLEMENTED]

POST /biomimicryPipeline

```typescript
interface Request {
  prompt: string;
  options?: {
    maxAttempts?: number;
    timeout?: number;
  };
}

interface Response {
  result: string;
  metadata: {
    attempts: number;
    duration: number;
    success: boolean;
  };
}
```

10.2 Internal APIs [IMPLEMENTED]

Orchestrator Flow

```typescript
interface OrchestrationConfig {
  maxAttempts: number;
  timeout: number;
  constitutionalRules: Rule[];
}

interface OrchestrationResult {
  success: boolean;
  output: string;
  metrics: ProcessMetrics;
}
```

11. Error Handling

11.1 Implemented Patterns

- Global error boundary
- Retry mechanisms
- Fallback states
- Error logging

11.2 Error Types

```
enum ErrorType {
  VALIDATION_ERROR = 'VALIDATION_ERROR',
  PROCESSING_ERROR = 'PROCESSING_ERROR',
  TIMEOUT_ERROR = 'TIMEOUT_ERROR',
  CONSTITUTIONAL_VIOLATION = 'CONSTITUTIONAL_VIOLATION'
}
```

12. Monitoring and Logging

12.1 Telemetry [IMPLEMENTED]

- Real-time metrics
- Performance monitoring
- Error tracking
- Usage statistics

12.2 Audit Logs [IMPLEMENTED]

- Decision trails
- Process steps
- Constitutional checks
- System events

13. Testing Strategy

13.1 Test Types

- Unit tests
- Integration tests
- Constitutional compliance tests
- Performance tests

13.2 Test Implementation

```
describe('Orchestrator Flow', () => {
  test('processes valid input successfully', async () => {
    // Test implementation
  });

  test('enforces constitutional constraints', async () => {
    // Test implementation
  });
});
```

14. Dependencies

14.1 Core Dependencies

- Firebase Admin SDK
- Genkit Framework
- Next.js
- TypeScript

14.2 Development Dependencies

- Firebase Emulator Suite
- Jest
- TypeScript Compiler
- ESLint

15. Future Roadmap

15.1 Short Term

1. Authentication implementation
2. Enhanced monitoring
3. Performance optimization

15.2 Long Term

1. Advanced scaling
2. Additional integrations
3. Extended constitutional rules

This technical specification describes the current implementation state of the Glass Box AI system. Components are clearly marked as implemented, partial, or planned.