CSCI 485: MongoDB Project Deliverable 3

Indexing, Workload Analysis & Relationship Design

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Event*Sphere* : Overview

EventSphere is a comprehensive event management platform built on MongoDB, demonstrating advanced NoSQL database design principles. The system supports geospatial event discovery, full-text search, and real-time check-ins across five core collections: events, venues, users, reviews, and checkins.

A. Indexing Strategy & Justification

2. Index Summary Table

Collection	Index Key(s)	Type	Purpose / Query Supported
events	`location`	2dsphere	Geospatial queries ($geoNear, $near)
events	`title, description, category, tags`	Text	Full-text search with relevance scoring
events	`category, startDate`	Compound	Category + date filtering
events	`eventType, startDate`	Compound	Polymorphic event type filtering
venues	`location`	2dsphere	Geospatial venue discovery

Collection	Index Key(s)	Type	Purpose / Query Supported
venues	`venueType, capacity`	Compound	Polymorphic venue filtering
venues	`name, description, amenities, address.city`	Text	Full-text venue search
venues	`venueType, rating`	Compound	Venue type + rating filtering
reviews	`eventId`	Single field	Reviews by event
reviews	`venueId`	Single field	Reviews by venue
reviews	`eventId, rating`	Compound	Event rating aggregations
reviews	`userId`	Single field	User review history
checkins	`eventId, userId`	Compound (Unique)	Prevent duplicate check-ins
checkins	`eventId`	Single field	Check-ins by event
checkins	`userId`	Single field	User attendance history
checkins	`venueId, checkInTime`	Compound	Venue time analytics
users	`email`	Single field (Unique)	User authentication
users	`createdAt`	Single field	User registration analytics
users	`lastLogin`	Single field	Active user identification
users	`profile.preferences.location`	2dsphere	Location-based user discovery

3. Index Creation Script

The attached `create_indexes.js` file contains the index creation script.

4. Index Reasoning

a) Geospatial Indexes (2dsphere)

Events Collection - Location Index

- **Query Pattern**: Find events within X km of user location
- **Frequency**: Very High (primary discovery feature)
- **Why this index type**: 2dsphere supports spherical distance queries on GeoJSON points, enabling $near/$geoNear for the map-based discovery I'd like to implement on a frontend, as described in the proposal and design docs.

Venues Collection - Location Index

- **Query Pattern**: Find venues near event location or user location
- **Frequency**: High (venue discovery and event creation)
- **Why this index type**: 2dsphere is required for distance queries on venues' GeoJSON points, matching the way events are created and venues are selected.

b) Text Search Indexes

Events Collection - Multi-field Text Index

- **Query Pattern**: Full-text search across title, description, category, and tags
- **Frequency**: Very High (primary search functionality)
- **Why this index type**: Text index provides tokenization, stemming, and relevance scoring across multiple fields, aligning with the full-text search requirement.

Venues Collection - Multi-field Text Index

- **Query Pattern**: Full-text search across venue name, description, amenities, and city
- **Frequency**: High (venue discovery and search functionality)
- **Why this index type**: Text index lets users find venues by name, amenities, and city in a single search, which is superior to multiple regex filters.

c) Compound Indexes for Common Query Patterns

Category + Date Filtering

- **Query Pattern**: "Technology events this weekend"
- **Frequency**: Very High (most common user filter)
- **Why this index type**: Compound index `{category: 1, startDate: 1}` supports equality on category and efficient range/sort on date consistent with discovery UI.

Geospatial + Date Filtering

- **Query Pattern**: "Events near me next month"
- **Frequency**: High (location + time filtering)
- **Why this index type**: Combining `location` (2dsphere) with `startDate` in a compound index supports geo filtering with a time window in a single index path when needed.

d) Polymorphic Indexes

Event Type Filtering

- **Query Pattern**: Filter by event type (virtual, hybrid, in-person, recurring)
- **Frequency**: High (event type is a primary discriminator)
- **Indexes**:
  - `{eventType: 1, startDate: 1}` - Type + date filtering
  - `{eventType: 1, category: 1}` - Type + category filtering
- **Why this index type**: Compound indexes align to polymorphic queries in the architecture, enabling selective filtering on the discriminator with a secondary field.

Venue Type Filtering

- **Query Pattern**: "Conference centers with high capacity"
- **Frequency**: Medium (venue selection and filtering)
- **Indexes**:
  - `{venueType: 1, capacity: 1}` - Type + capacity filtering
  - `{venueType: 1, rating: 1}` - Type + quality filtering
- **Why this index type**: Compound indexes on `venueType` plus a numeric field support the most common admin/user filters without requiring multiple single-field scans.

e) Extended Reference Pattern Indexes

Venue Reference Optimization

- **Query Pattern**: Filter events by venue type or city without joins
- **Frequency**: Medium (venue-based filtering)
- **Indexes**:
  - `{venueReference.venueType: 1, startDate: 1}` - Venue type + date
  - `{venueReference.city: 1, startDate: 1}` - City + date
  - `{venueReference.capacity: 1}` - Capacity sorting
- **Why this index type**: These compound indexes on the denormalized venue reference fields make it easy to filter events by venue details right inside the events collection, so there's no need to join or look up in the `venues` collection.

f) Analytics and Aggregation Indexes

Reviews Aggregation

- **Query Pattern**: Calculate average ratings per event/venue
- **Frequency**: High (rating calculations)
- **Indexes**:
  - `{eventId: 1, rating: 1}` - Event rating aggregations
  - `{venueId: 1, rating: 1}` - Venue rating aggregations
- **Why this index type**: These compund indexes support rating calculations and aggregations.

Check-ins Analytics

- **Query Pattern**: Attendance patterns, peak hours, user behavior
- **Frequency**: High (analytics and reporting)
- **Indexes**:
  - `{venueId: 1, checkInTime: 1}` - Venue time analytics
  - `{userId: 1, checkInTime: 1}` - User attendance patterns
- **Why this index type**: These compound indexes support attendance patterns and user behavior analytics.

g) Data Integrity Indexes

Duplicate Prevention

- **Query Pattern**: Prevent duplicate check-ins per user/event
- **Frequency**: High (data integrity)

- **Index**: `{eventId: 1, userId: 1}` (Unique)
- **Why this index type**: This unique compound index prevents duplicate check-ins per user/event at write time.

B. Workload & Operations Analysis

Most Common Database Operations

Operation	Type	Criticality	Frequency	Target Collection(s)
Event discovery near a location (with optional date/category filters)	Read	High	Many per minute	events
Full-text event search	Read	High	Many per minute	events
Filter events by type (virtual/in-person/hybrid/recurring)	Read	High	Many per minute	events
User check-in (prevent duplicates)	Write	High	Many per minute (during events)	checkins
Fetch reviews for an event/venue	Read	Medium	Several per minute	reviews
Venue discovery near a location	Read	Medium	Several per minute	venues
User login by email	Read	High	Many per minute	users
Attendance analytics by venue/time	Aggregate	Medium	Few per hour	checkins
User attendance history	Read	Medium	Several per minute	checkins
Event updates (CRUD)	Update/Write	Medium	Several per minute	events

Why these operations are indexed

- Event discovery: 2dsphere on `events.location` and a compound `{category, startDate}` so map + date/category filters stay fast.
- Full-text search: Text index on `events.title, description, category, tags` to surface relevant results with one query.
- Event type filters: `{eventType, startDate}` to pair the discriminator with the common date window.
- Check-ins: Unique `{eventId, userId}` to hard-stop duplicates at write time.

- Reviews: `{eventId}`, `{venueId}`, and `{eventId, rating}` to load reviews quickly and support averages.
- Venues: 2dsphere on `venues.location` for "near me", plus `{venueType, capacity}` for selection flows.
- Users: Unique `{email}` for quick login lookups; `{lastLogin}` and `{createdAt}` for simple reporting.

C. Design Patterns Used & Anti-Patterns Avoided

Design Patterns Used

1. Extended Reference Pattern

Why this pattern was used: Events store denormalized venue data for easier querying of venue details.

```
// Event document with extended venue reference
{
  "_id": ObjectId("..."),
  "title": "Tech Conference 2024",
  "venueId": ObjectId("venue..."),
  "venueReference": {
    "name": "Convention Center",
    "city": "San Francisco",
    "capacity": 5000,
    "venueType": "conferenceCenter"
  },
  // ... other fields
}
```

Benefits:

- **Query Performance**: Avoids joins when filtering events by venue type or city
- **Reduced Lookups**: Venue information is available in event queries without additional database calls
- **Better User Experience**: Event listings show venue details immediately without extra queries

2. Computed Pattern

Why this pattern was used: Pre-calculated statistics stored in documents to improve query performance and provide a single source of truth for statistics.

```
// Event with computed statistics
{
  "_id": ObjectId("..."),
  "title": "Tech Conference 2024",
  "currentAttendees": 150,
  "maxAttendees": 200,
  "computedStats": {
    "totalTicketsSold": 180,
```

```
      "totalRevenue": 45000,
      "attendanceRate": 75.0,
      "reviewCount": 23,
      "averageRating": 4.2,
      "lastUpdated": ISODate("2024-01-15T10:30:00Z")
    }
  }
```

Benefits:

- **Performance**: Eliminates expensive aggregations for dashboard queries
- **Consistency**: Single source of truth for statistics
- **Real-time Updates**: Statistics updated via application triggers

When stats are updated:

- Tickets are sold/refunded
- Reviews are added/updated
- Events are created/completed
- Check-ins happen

3. Polymorphic Pattern

Implementation: Single collection with type-specific fields for different entity types.

Event Polymorphism

```
// Virtual event
{
  "eventType": "virtual",
  "virtualDetails": {
    "platform": "Zoom",
    "meetingUrl": "https://zoom.us/j/123456789",
    "recordingAvailable": true,
    "timezone": "PST"
  }
}

// Hybrid event
{
  "eventType": "hybrid",
  "hybridDetails": {
    "virtualCapacity": 500,
    "inPersonCapacity": 100,
    "virtualMeetingUrl": "https://teams.microsoft.com/j/987654321"
  }
}
```

Venue Polymorphism

```
// Conference center venue
{
  "venueType": "conferenceCenter",
  "conferenceCenterDetails": {
    "breakoutRooms": 12,
    "avEquipment": ["Video Conferencing", "Projectors", "Whiteboards"],
    "cateringAvailable": true
  }
}

// Park venue
{
  "venueType": "park",
  "parkDetails": {
    "outdoorSpace": true,
    "parkingSpaces": 200,
    "restroomFacilities": true
  }
}
```

Benefits:

- **Schema Flexibility**: Different types can have specialized attributes
- **Query Efficiency**: Filter by type using discriminator field
- **Maintainability**: Single collection for related entity types
- **Extensibility**: Easy to add new types without schema changes

4. Schema Versioning Pattern

Implementation: All collections include `schemaVersion` field for future evolution.

```
// All documents include schema version
{
  "_id": ObjectId("..."),
  "schemaVersion": "1.0",
  // ... other fields
}
```

Benefits:

- **Safe Evolution**: Add new fields without breaking existing data
- **Gradual Migration**: Update documents in batches by version
- **Rollback Capability**: Revert to previous schema if needed

Anti-Patterns Avoided

1. Bloated Documents

Anti-Pattern: Storing large, too much data in a single document.

Why I avoided this anti-pattern:

- **Document Size Limit**: MongoDB has 16MB document size limit
- **Write Performance**: Updating user document becomes expensive
- **Memory Usage**: Large documents consume excessive RAM, and make for less efficient queries.
- **Query Performance**: Filtering embedded arrays is inefficient, making it harder to query reviews.

My Solution: Separate `reviews` collection with references to `users` and `events`.

2. Over-Indexing

Anti-pattern: Creating indexes for every possible query without considering write performance.

What I did wrong initially: I had 30+ indexes across all collections, including single-field indexes on every possible filter field.

Why this was bad:

- **Write Performance**: Each index slows down insert/update operations
- **Storage Overhead**: Index storage was larger than data storage
- **Memory Usage**: Too many indexes consumed excessive RAM

My solution: Reduced to 4 indexes per collection, focusing on compound indexes that support multiple query patterns.

3. Over-Embedding Large Subdocuments

Anti-pattern: Storing large arrays or subdocuments that grow unbounded.

Why I avoided this: Instead of embedding all user check-ins in the `users` collection, I created a separate `checkins` collection.

What would have been bad:

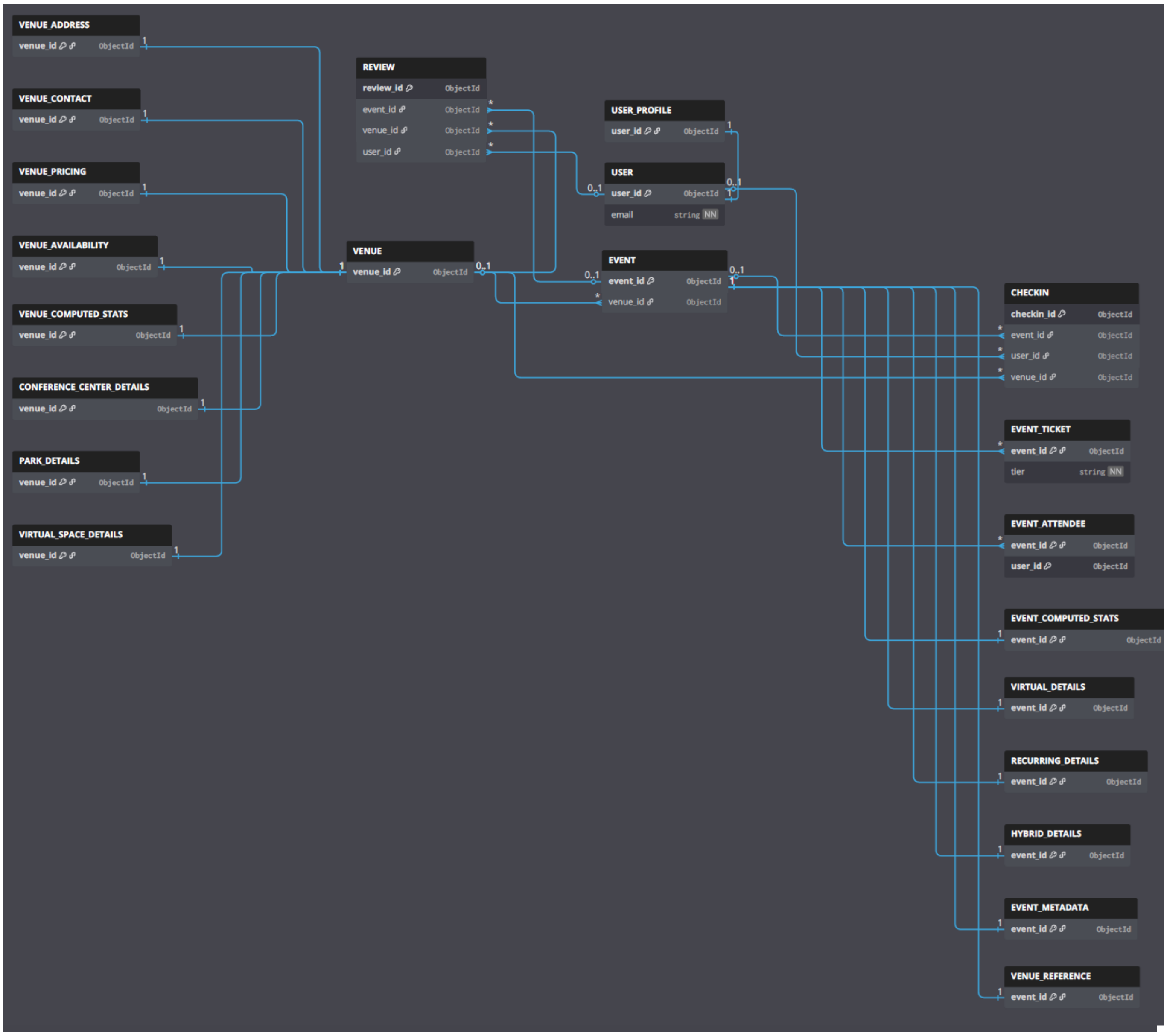
- **Document Size**: User documents would grow indefinitely with each check-in
- **Write Performance**: Updating a user document becomes slower as it grows
- **Query Performance**: Filtering embedded arrays is inefficient

My solution: Separate `checkins` collection with references to `users` and `events`, enabling efficient analytics queries without bloating user documents.

D. Relationship & Schema Diagrams

1. ER Diagram

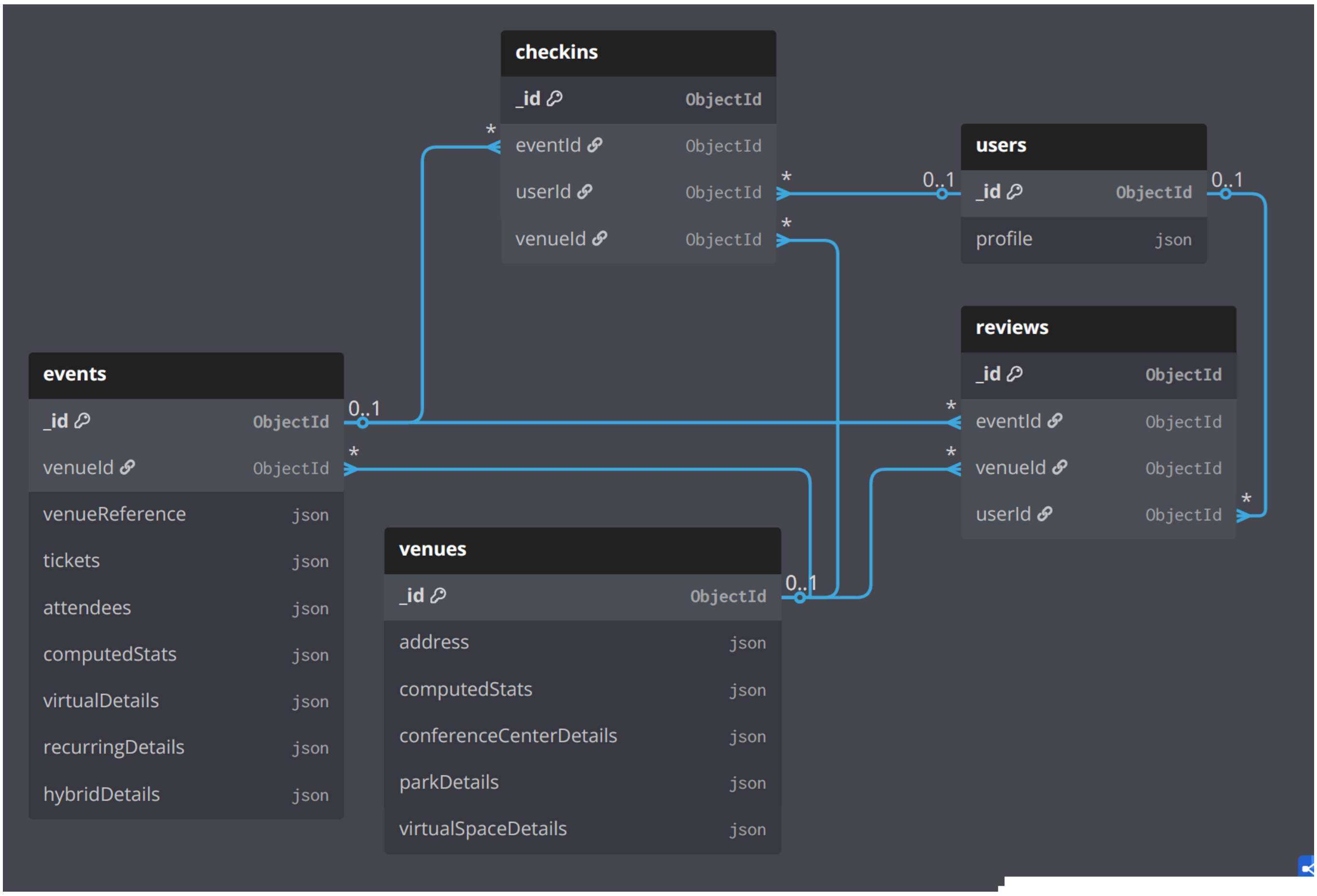
The ER diagram below provides a detailed view of the database schema and relationships:



> *Figure 1: EventSphere Entity Relationship Diagram - Detailed schema showing key fields and relationships between entities.*

2. Collection Relationship Diagram

The following diagram illustrates the relationships between the five core collections in EventSphere:



> *Figure 2: EventSphere Collection Relationships - Shows the relationships between events, venues, users, reviews, and checkins collections with their key fields and reference patterns.*

Key Relationships Explained

1. **Events** ↔ **Venues**: Events reference venues through `venueId` and include denormalized venue data in `venueReference` for performance
2. **Events** ↔ **Users**: Users can create events (creator relationship) and check into events (many-to-many through checkins)
3. **Events** ↔ **Reviews**: Reviews reference events through `eventId` for event-specific feedback
4. **Venues** ↔ **Reviews**: Reviews reference venues through `venueId` for venue-specific feedback
5. **Users** ↔ **Checkins**: Users have many checkins, creating attendance history
6. **Events** ↔ **Checkins**: Events have many checkins, tracking attendance

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GeoJSON

GeoJSON Implementation

GeoJSON is used to store geospatial data to support geospatial operations. Types of GeoJSON objects used are Point, LineString, and Polygon. One can then query the database for geospatial data using the $geoNear and $near operators, as well as the 2dsphere index.

EventSphere leverages MongoDB's native GeoJSON Point support for geospatial operations which is used in the `events` and `venues` collections.

```
// Event or Venue location using GeoJSON Point
{
  "location": {
    "type": "Point",
    "coordinates": [-122.4194, 37.7749] // [longitude, latitude]
  }
}
```

Geospatial Query Examples

```
// Find events within 10km of user location
db.events.find({
  location: {
    $near: {
      $geometry: {
        type: "Point",
        coordinates: [-122.4194, 37.7749]
      },
      $maxDistance: 10000 // 10km in meters
    }
  }
})

// Find venues at least 5km away from user location
db.venues.find({
  location: {
    $near: {
      $geometry: {
        type: "Point",
        coordinates: [-122.4194, 37.7749]
      },
      $minDistance: 5000 // 5km in meters
    }
  }
})
```