American University of Science and Technology
Faculty of Engineering and Computer Science
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CSI418L: Web Programming Lab

Web Bluetooth Medical/Fitness Dashboard

by

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A Final Project Report

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APPROVAL PAGE

This is to certify that the project report entitled

"Web Bluetooth Medical/Fitness Dashboard"

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has been approved by the project advisor.

Dr. Samir Saad
Project Advisor

Date: _____

"The Web as I envisaged it, we have not seen it yet.
The future is still so much bigger than the past."

— Tim Berners-Lee

Abstract

The Web Bluetooth Medical/Fitness Dashboard is a comprehensive web application that demonstrates the integration of modern web technologies with physical hardware devices for health monitoring purposes. The system leverages the Web Bluetooth API to establish direct connections with Bluetooth Low Energy (BLE) devices including heart rate monitors, digital thermometers, and ESP32-based custom sensors, enabling real-time physiological data acquisition without requiring native application development.

The application employs a robust architecture built on ASP.NET Core 6 MVC framework with C# for server-side processing, utilizing the Data Transfer Object View Model (DTOVM) design pattern for clean separation of concerns. Language Integrated Query (LINQ) provides powerful data manipulation capabilities including GroupBy operations for aggregating readings by device type, Average calculations for statistical analysis, and complex filtering operations using Where clauses. The frontend implementation combines HTML5 semantic markup, CSS3 with gradient-based responsive design, and JavaScript ES6+ for client-side interactivity.

jQuery library handles DOM manipulation and AJAX communications, while jQuery Animate delivers smooth user interface transitions and real-time visual feedback through pulse animations when new data arrives. Data interchange supports both JSON for API communication and XML export through LINQ to XML transformations. A PHP script provides supplementary server-side data processing including BMI calculations, heart rate zone classification, and temperature status analysis.

External API integrations extend functionality by fetching global COVID-19 statistics, air quality metrics, and health tips from third-party services. The system addresses several technical challenges including binary GATT characteristic parsing according to Bluetooth specifications, low-latency real-time visualization, and cross-origin resource sharing configuration.

This project demonstrates practical implementation of web programming concepts while providing a functional health monitoring solution that bridges the gap between web applications and physical sensor hardware.

Keywords: Web Bluetooth API, ASP.NET Core MVC, LINQ, Real-time Data, Health Monitoring, jQuery, BLE Devices

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The team also acknowledges the open-source communities behind the technologies utilized in this project, including the ASP.NET Core framework, Bootstrap, Font Awesome, and the various public APIs that enhanced the application's functionality.

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List of Abbreviations

AJAX	Asynchronous JavaScript and XML
API	Application Programming Interface
BLE	Bluetooth Low Energy
BMI	Body Mass Index
BPM	Beats Per Minute
CORS	Cross-Origin Resource Sharing
CSS	Cascading Style Sheets
DFD	Data Flow Diagram
DOM	Document Object Model
DTO	Data Transfer Object
DTOVM	Data Transfer Object View Model
ES6	ECMAScript 2015
GATT	Generic Attribute Profile
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HTTPS	HyperText Transfer Protocol Secure
JSON	JavaScript Object Notation
LINQ	Language Integrated Query
MVC	Model-View-Controller
PHP	PHP: Hypertext Preprocessor
REST	Representational State Transfer
SDK	Software Development Kit
UI	User Interface
UUID	Universally Unique Identifier
XML	Extensible Markup Language

Chapter 1

Introduction and Background

1.1 Introduction

The convergence of web technologies and hardware connectivity represents a significant advancement in modern application development. Traditional approaches to interfacing with Bluetooth devices required native application development on specific platforms, creating barriers for rapid prototyping and cross-platform deployment. The introduction of the Web Bluetooth API by the World Wide Web Consortium (W3C) fundamentally changed this paradigm by enabling direct communication between web browsers and Bluetooth Low Energy (BLE) devices.

This project develops a comprehensive Medical/Fitness Dashboard that demonstrates the practical application of web technologies for health monitoring purposes. The system connects to physical hardware including heart rate monitors conforming to the standard Bluetooth Heart Rate Service, digital thermometers implementing the Health Thermometer Service, and custom ESP32-based sensor devices. Real-time data flows from these devices through the browser directly to the server infrastructure, enabling visualization, storage, and analysis without intermediate native applications.

The application serves as an educational demonstration of the technologies covered in the CSI418L Web Programming Lab course while providing genuine utility for health data collection and monitoring. By implementing the full technology stack from client-side JavaScript to server-side C# processing, the project illustrates the complete data pipeline in modern web development.

The choice of health monitoring as the application domain provides concrete, measurable data types that clearly demonstrate the system's capabilities. Heart rate values in beats per minute, temperature readings in degrees Celsius, and custom sensor values create an intuitive interface for understanding data flow and processing.

1.2 Background

Web-based health monitoring systems have evolved significantly over the past decade. Initial implementations relied on manual data entry or required users to install dedicated applications on their devices. The emergence of wearable fitness trackers and medical-grade monitoring devices created demand for seamless data integration across platforms.

The Web Bluetooth API, achieving Working Draft status at W3C, provides JavaScript interfaces for discovering and communicating with BLE devices. The API operates within strict security constraints: connections require user gesture initiation (such as button clicks), operate only over HTTPS or localhost, and implement permission prompts before device access. These security measures protect user privacy while enabling powerful hardware integration capabilities.

Bluetooth Low Energy, standardized as Bluetooth 4.0 and enhanced in subsequent versions, provides energy-efficient wireless communication optimized for small, battery-powered devices. BLE implements a client-server architecture using the Generic Attribute Profile (GATT), organizing data into Services containing Characteristics. Standard services exist for common device types: the Heart Rate Service (UUID 0x180D) and Health Thermometer Service (UUID 0x1809) provide interoperability across manufacturers.

ASP.NET Core emerged as Microsoft's cross-platform, high-performance framework for building modern web applications. The Model-View-Controller pattern separates concerns into distinct components: Models represent data structures, Views handle presentation, and Controllers manage request processing. Language Integrated Query (LINQ) extends C# with powerful data manipulation capabilities, enabling SQL-like operations on collections including filtering, ordering, grouping, and aggregation.

The combination of these technologies creates a full-stack development environment where strongly-typed server-side code processes requests, performs business logic, and returns data to dynamically-rendered client interfaces. jQuery simplifies client-side development through its selector engine and AJAX utilities, while CSS3 provides sophisticated styling capabilities including gradients, animations, and responsive layouts.

1.3 Specific Objectives

The project establishes the following specific objectives aligned with course learning outcomes:

1. **Web Bluetooth Integration:** Implement device discovery and connection for BLE heart rate monitors, thermometers, and ESP32 devices using the Web Bluetooth API with proper GATT characteristic parsing.
2. **ASP.NET Core MVC Implementation:** Develop a server-side application following the Model-View-Controller pattern with proper routing, dependency injection, and RESTful API endpoints.
3. **LINQ Query Operations:** Demonstrate comprehensive LINQ usage including GroupBy for device aggregation, Average for statistical calculations, Where for filtering, OrderBy for sorting, and Select for projections.
4. **Data Format Support:** Implement JSON serialization for API communication and XML generation using LINQ to XML for data export functionality.
5. **jQuery Implementation:** Utilize jQuery for DOM manipulation, event handling, AJAX requests, and animate methods for user interface transitions.
6. **PHP Integration:** Develop PHP scripts for supplementary data processing including BMI calculation, heart rate classification, and temperature analysis.
7. **Responsive Design:** Create a modern user interface using HTML5 semantic elements, CSS3 styling with gradients and animations, and Bootstrap 5 responsive framework.
8. **External API Integration:** Incorporate third-party APIs for health tips, COVID-19 statistics, and air quality data to demonstrate cross-origin data fetching.
9. **Real-time Visualization:** Display live sensor data with visual feedback including pulse animations and automatic table updates.
10. **Security Implementation:** Apply proper HTTPS requirements, user consent mechanisms, input validation, and CORS configuration.

These objectives ensure comprehensive coverage of the course curriculum while producing a functional, demonstrable application.

Chapter 2

Problem Statement Overview

2.1 The Problem

Modern health monitoring increasingly relies on wearable devices and sensors that collect physiological data continuously. However, several challenges impede effective utilization of this data:

Platform Fragmentation: Traditional approaches require native application development for each target platform (iOS, Android, Windows, macOS). This multiplies development effort and creates inconsistent user experiences across devices.

Installation Barriers: Users must discover, download, and install dedicated applications before accessing device functionality. This friction reduces adoption rates, particularly for occasional-use scenarios.

Data Isolation: Proprietary applications often store data in isolated silos, preventing aggregation and cross-device analysis. Users cannot easily combine data from different manufacturers or device types.

Development Complexity: Native Bluetooth development requires platform-specific expertise, specialized development environments, and understanding of complex protocol stacks. Web developers lack accessible tools for hardware integration.

Real-time Processing: Health monitoring requires low-latency data handling to provide meaningful feedback. Traditional request-response web architectures struggle with continuous data streams.

The Web Bluetooth Medical/Fitness Dashboard addresses these challenges by providing:

- Cross-platform compatibility through browser-based deployment
- Zero-installation access via URL navigation
- Unified data collection from multiple device types
- Familiar web development technologies and patterns

- Real-time visualization with sub-second update latency

The system demonstrates that modern web technologies can effectively bridge the gap between browser applications and physical hardware, enabling rapid development of IoT-enabled web applications.

2.2 Literature Overview

The intersection of web technologies and hardware connectivity has generated significant research interest. This section reviews relevant literature and existing solutions that inform the project design.

2.2.1 Web Bluetooth API Development

The Web Bluetooth API specification, developed by the W3C Web Bluetooth Community Group, defines JavaScript interfaces for BLE device interaction. The API implements security-first design principles requiring HTTPS contexts and user gestures for connection initiation. Browser support varies, with Chrome, Edge, and Opera providing full implementations while Firefox and Safari offer limited or experimental support.

2.2.2 Health Monitoring Systems

The global digital health market continues rapid expansion, with wearable device shipments exceeding 500 million units annually. Standards organizations including Bluetooth SIG and Continua Health Alliance define interoperability profiles ensuring device compatibility.

Open-source platforms such as Open mHealth provide data schemas and processing pipelines for health information. Their JSON-based data formats influenced the design of the dashboard's data transfer objects.

2.2.3 ASP.NET Core Architecture

Microsoft's ASP.NET Core documentation provides comprehensive guidance on MVC pattern implementation, dependency injection, and middleware configuration. The framework's cross-platform nature enables deployment flexibility across Windows, Linux, and macOS environments.

2.2.4 LINQ Query Patterns

LINQ's integration into C# provides type-safe query capabilities over diverse data sources. Research comparing LINQ to traditional loops demonstrates improved code readability and maintainability, though with potential performance considerations for large datasets.

GroupBy operations specifically enable efficient data aggregation without explicit loop constructs, supporting the dashboard's analytics features that categorize readings by device type and time period.

2.2.5 jQuery and Frontend Development

Despite the emergence of modern frameworks including React, Vue, and Angular, jQuery remains prevalent in web development, particularly for progressive enhancement of server-rendered applications. The library's stable API and extensive plugin ecosystem provide reliable solutions for DOM manipulation and AJAX communication.

CSS3 capabilities including gradients, transforms, and keyframe animations enable sophisticated visual effects previously requiring JavaScript or Flash. The dashboard leverages these capabilities for pulse animations and smooth transitions that provide visual feedback for real-time data updates.

2.2.6 PHP Data Processing

PHP continues serving a significant portion of web applications, with WordPress alone powering approximately 40% of websites. The language's straightforward syntax and extensive function library make it suitable for data processing scripts that complement primary application logic.

2.2.7 Related Systems

Existing health dashboard implementations include:

- **Google Fit:** Native applications with limited web functionality, requiring Google account integration.
- **Apple Health:** iOS-exclusive with no web interface, demonstrating platform lock-in issues.
- **Fitbit Web Dashboard:** Web-accessible but requires proprietary device ecosystem and cloud synchronization.

- **Home Assistant:** Open-source home automation platform supporting some BLE devices through add-ons, requiring dedicated server hardware.

The Web Bluetooth Medical/Fitness Dashboard differentiates itself through direct browser-to-device communication without intermediate cloud services, immediate deployment via URL, and support for standard Bluetooth health profiles alongside custom ESP32 devices.

Chapter 3

Proposed Solutions

This chapter presents the proposed solution architecture for the Web Bluetooth Medical/Fitness Dashboard, detailing the approach taken to address the identified problems through integration of web technologies and Bluetooth hardware connectivity.

3.1 Solution Overview

The proposed solution implements a three-tier web architecture enhanced with client-side Bluetooth connectivity:

1. **Presentation Tier:** Browser-based interface using HTML5, CSS3, Bootstrap 5, and jQuery providing responsive, animated user experience with Web Bluetooth device management.
2. **Application Tier:** ASP.NET Core 6 MVC server handling HTTP requests, executing LINQ queries, managing session state, and rendering views with Razor syntax.
3. **Data Tier:** In-memory data storage using C# collections with LINQ-enabled querying, plus PHP scripts for supplementary processing.

3.2 Web Bluetooth Integration Strategy

The solution leverages the Web Bluetooth API to establish direct connections between the browser and BLE devices. This approach eliminates the need for native application development while maintaining real-time data acquisition capabilities.

Key implementation decisions include:

- **Standard Service Support:** Implementation of standard Bluetooth SIG services (Heart Rate Service 0x180D, Health Thermometer Service 0x1809) ensures compatibility with commercial devices.

- **Generic Device Support:** The `acceptAllDevices` filter option enables connection to ESP32 and other custom devices without predefined service filters.
- **Binary Parsing:** GATT characteristics return binary data requiring proper parsing according to Bluetooth specifications. The solution implements DataView operations for extracting values from byte arrays.
- **Event-Driven Updates:** The `characteristicvaluechanged` event provides real-time notifications when device values update, enabling immediate visualization without polling.

3.3 Data Flow Architecture

Data flows through the system following this sequence:

1. User initiates device connection via button click (required user gesture)
2. Browser displays native Bluetooth device picker
3. User selects target device
4. Web Bluetooth API establishes GATT connection
5. Application subscribes to relevant characteristics
6. Device pushes value updates via notifications
7. JavaScript parses binary data and updates UI
8. jQuery AJAX posts reading to server endpoint
9. Controller validates and stores reading via service
10. LINQ queries aggregate data for dashboard display

3.4 Server-Side Processing

The ASP.NET Core MVC application implements:

- **HealthController:** RESTful API endpoints for CRUD operations on health readings
- **HealthDataService:** Business logic layer with LINQ query implementations
- **DTOs:** `HealthReadingDto`, `HealthDashboardViewModel`, `DeviceConnectionDto` for type-safe data transfer

- **Dependency Injection:** Service registration in `Program.cs` enabling testability and loose coupling

3.5 Frontend Implementation

Client-side code provides:

- **Device Management:** `web-bluetooth. js` encapsulates Bluetooth operations in `BluetoothHealthDevice` class
- **UI Interactions:** `dashboard.js` handles button events, table updates, and animations
- **Visual Design:** `dashboard.css` implements gradient backgrounds, card transitions, and responsive layouts
- **Semantic Markup:** Razor views using HTML5 elements with ARIA accessibility attributes

3.6 PHP Supplementary Processing

The `health-processor.php` script provides:

- BMI calculation from weight and height inputs
- Heart rate zone classification based on age-adjusted maximum heart rate
- Temperature status classification (normal, fever, hypothermia)
- Batch data analysis returning JSON responses

3.7 External API Integration

The solution incorporates third-party data sources:

- **COVID-19 Statistics:** disease.sh API providing global case counts
- **Air Quality:** OpenAQ API for environmental health data
- **Health Quotes:** API Ninjas for motivational health tips

3.8 Security Measures

Security implementation includes:

- HTTPS requirement for Web Bluetooth API operation
- User consent through native browser device picker
- Server-side input validation using ModelState
- CORS headers configured for cross-origin API access
- No persistent sensitive data storage (in-memory only)

This comprehensive solution addresses the identified problems while demonstrating proficiency in the full technology stack covered by the CSI418L curriculum.

Chapter 4

Design Specifications

This chapter presents the technical design specifications for the Web Bluetooth Medical/Fitness Dashboard through architectural diagrams and detailed component descriptions.

4.1 System Architecture

The system architecture implements a layered design separating concerns across presentation, business logic, and data access components. Figure 4.1 illustrates the high-level architecture.

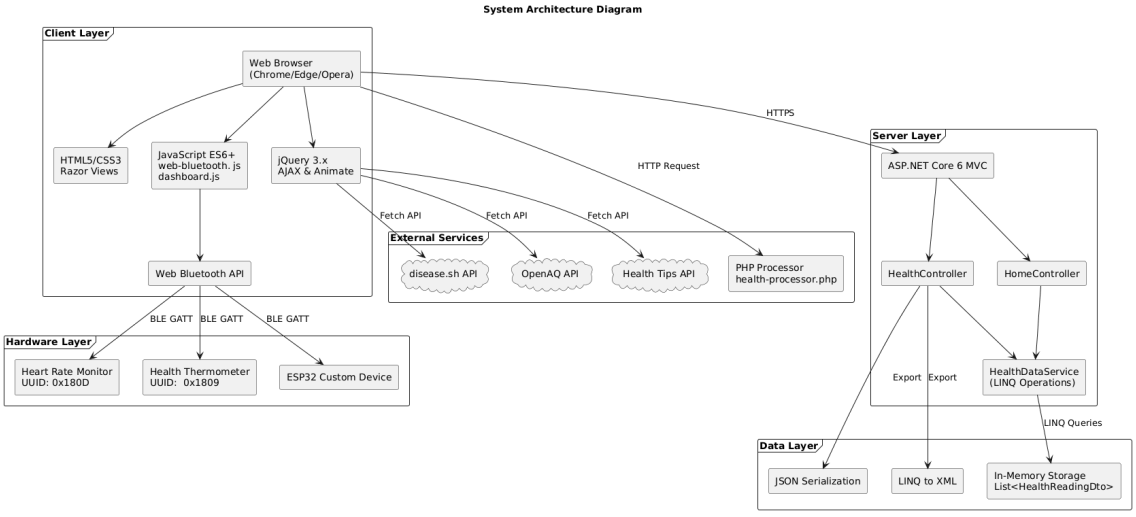

Figure 4.1: System Architecture Overview

The architecture comprises the following layers:

4.1.1 Client Layer

- **Browser Runtime:** Chrome, Edge, or Opera with Web Bluetooth support
- **HTML5 Views:** Razor-rendered pages with semantic markup
- **CSS3 Styling:** Custom stylesheet with Bootstrap 5 framework

- **JavaScript Modules:** `web-bluetooth.js` and `dashboard.js`
- **jQuery Library:** DOM manipulation and AJAX communication

4.1.2 Server Layer

- **ASP.NET Core 6:** Cross-platform web framework
- **Controllers:** `HomeController`, `HealthController`
- **Services:** `HealthDataService` with LINQ operations
- **Models:** DTOs and ViewModels for data transfer
- **Views:** Razor templates in MVC structure

4.1.3 Data Layer

- **In-Memory Storage:** Static `List<HealthReadingDto>` collection
- **LINQ Queries:** GroupBy, Where, OrderBy, Select, Average operations
- **Export Formats:** JSON serialization and LINQ to XML generation

4.1.4 External Integration

- **BLE Devices:** Standard and custom Bluetooth peripherals
- **Third-Party APIs:** REST endpoints for supplementary data
- **PHP Processing:** Server-side health calculations

4.2 Data Flow Diagram

Figure 4.2 presents the Level 0 Data Flow Diagram showing major data movements through the system.

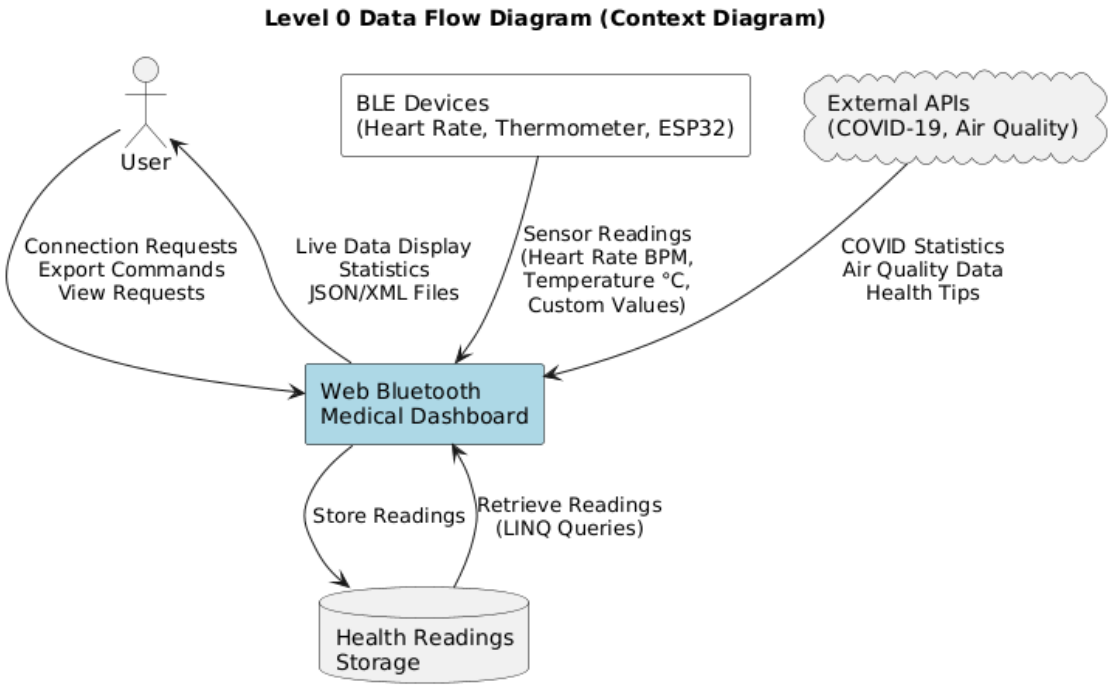

Figure 4.2: Level 0 Data Flow Diagram

External Entities:

- **User:** Initiates connections, views data, exports reports
- **BLE Devices:** Heart rate monitors, thermometers, ESP32 sensors
- **External APIs:** COVID-19, air quality, health tips services

Data Flows:

- **Connection Request:** User → System (device selection)
- **Sensor Data:** BLE Devices → System (health readings)
- **Display Data:** System → User (charts, tables, statistics)
- **Export Data:** System → User (JSON/XML files)
- **API Data:** External APIs → System (supplementary info)

4.3 Use Case Diagram

Figure 4.3 illustrates the use cases supported by the system.

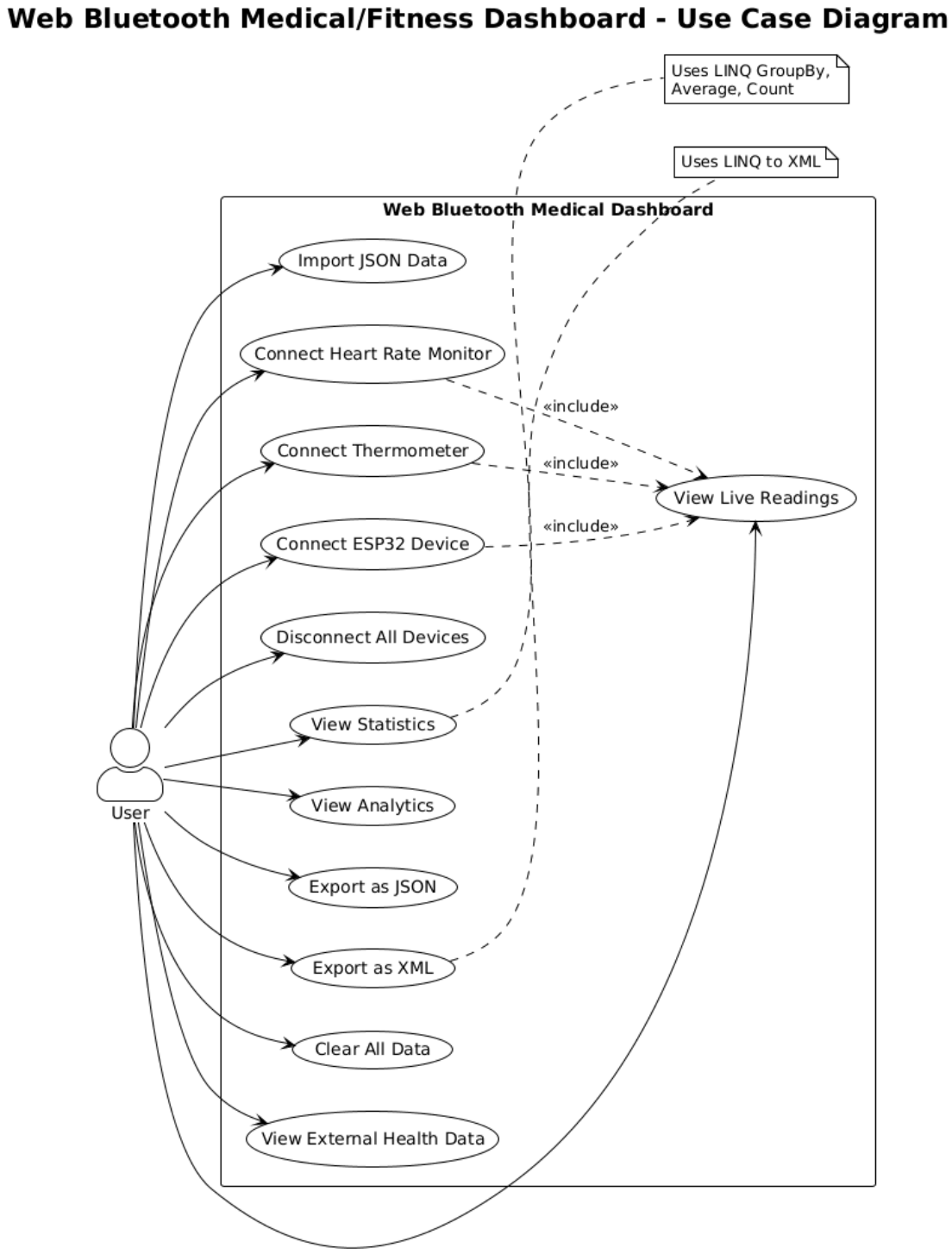

Figure 4.3: Use Case Diagram

Table 4.1 provides detailed descriptions of primary use cases.

Table 4.1: Use Case Descriptions

Use Case	**Description**
Connect Heart Rate Monitor	User clicks button, selects device from browser picker, system establishes GATT connection and subscribes to heart rate measurements
Connect Thermometer	User initiates connection to health thermometer device, system receives temperature readings via notifications
Connect ESP32 Device	User connects to custom ESP32 sensor, system starts simulated/real data streaming
View Live Readings	User observes real-time values displayed in stat cards with pulse animations on updates
View Statistics	User sees LINQ-aggregated statistics including totals, averages, and device counts
Export as JSON	User downloads all readings as formatted JSON file
Export as XML	User downloads all readings as XML document generated via LINQ to XML

4.4 Basic Sequence Diagram

Figure 4.4 presents the sequence diagram for the core feature of connecting a heart rate monitor and receiving data.

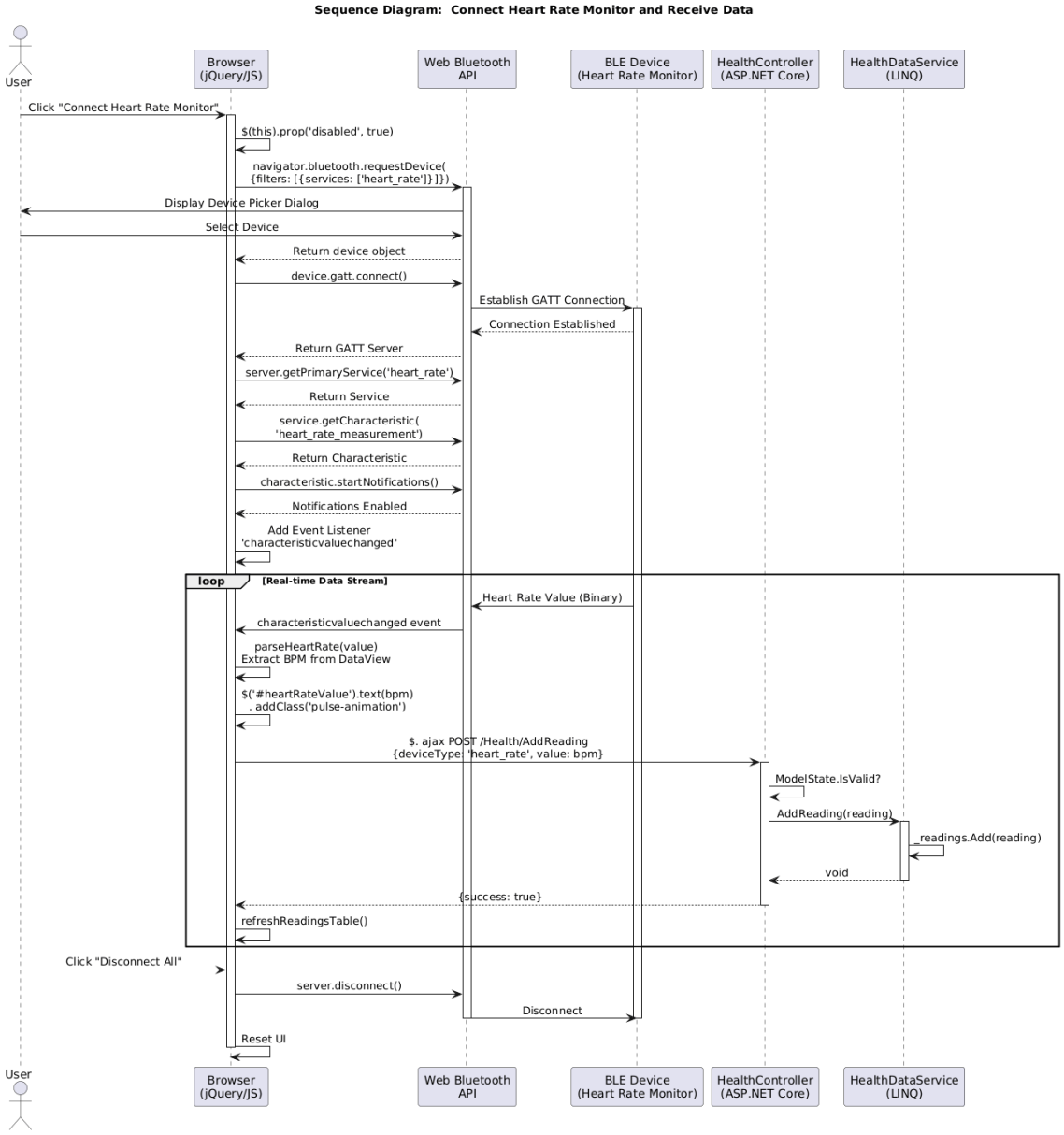

Figure 4.4: Sequence Diagram: Connect Heart Rate Monitor and Receive Data

The sequence involves:

1. User clicks “Connect Heart Rate Monitor” button
2. JavaScript calls `navigator.bluetooth.requestDevice()` with heart_rate filter
3. Browser displays native device picker dialog
4. User selects device from list
5. API returns device object
6. JavaScript calls `device.gatt.connect()`

7. Connection established, returns GATT server
8. JavaScript calls `server.getPrimaryService('heart_rate')`
9. Service object returned
10. JavaScript calls `service.getCharacteristic('heart_rate_measurement')`
11. Characteristic object returned
12. JavaScript calls `characteristic.startNotifications()`
13. Event listener added for `characteristicvaluechanged`
14. Device sends heart rate value (repeating)
15. Event fires with DataView value
16. `parseHeartRate()` extracts BPM from binary
17. UI updated with jQuery animation
18. AJAX POST to `/Health/AddReading`
19. Controller validates and calls service
20. Service adds reading to collection
21. Response returned to browser

4.5 Workflow Diagram

Figure 4.5 illustrates the overall application workflow from user arrival to data export.

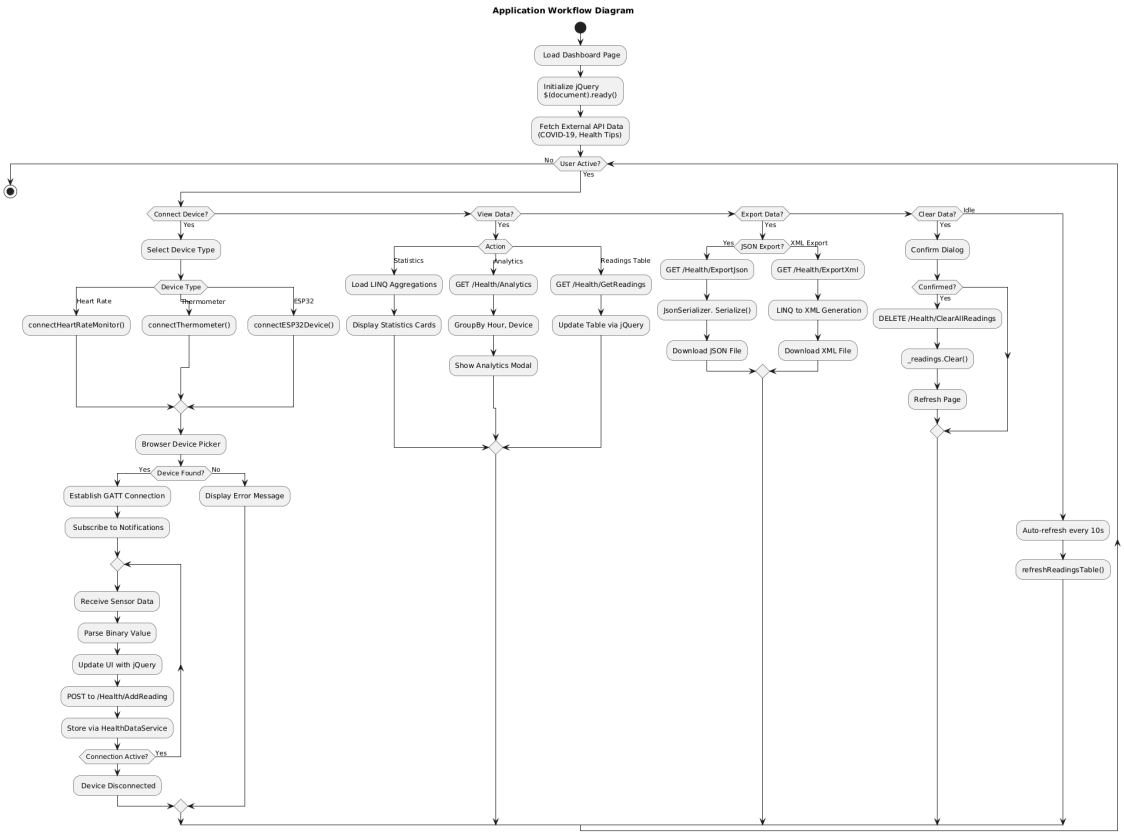

Figure 4.5: Application Workflow Diagram

The workflow supports multiple concurrent device connections, continuous data streaming until user disconnects, and export operations at any time during the session.

Chapter 5

Methodology and Implementation

This chapter details the implementation methodology and presents key software modules comprising the Web Bluetooth Medical/Fitness Dashboard.

5.1 Development Methodology

The project follows an iterative development approach with the following phases:

1. **Requirements Analysis:** Identifying course requirements and feature specifications
2. **Architecture Design:** Defining system layers and component interactions
3. **Incremental Implementation:** Building features iteratively with continuous testing
4. **Integration Testing:** Validating component interactions and data flow
5. **Documentation:** Preparing technical documentation and user guides

5.2 Software Modules

5.2.1 Project Structure

The application follows standard ASP.NET Core MVC conventions:

```
Web-Final/
|- README.md
|- TECHNICAL_DOCUMENTATION.md
|- SETUP_GUIDE.md
|- . gitignore
|- HealthDashboard/
    |- Program.cs
    |- HealthDashboard.csproj
    |- Controllers/
```

```
|   |- HomeController.cs
|   |- HealthController.cs
|- Models/
|   |- HealthReadingDto.cs
|   |- HealthDashboardViewModel.cs
|   |- DeviceConnectionDto.cs
|- Services/
|   |- HealthDataService.cs
|- Views/
|   |- Home/
|   |   |- Index.cshtml
|   |- Health/
|   |   |- Index.cshtml
|   |- Shared/
|       |- _Layout.cshtml
|- wwwroot/
    |- css/
    |   |- dashboard.css
    |   |- site.css
    |- js/
    |   |- web-bluetooth.js
    |   |- dashboard.js
    |   |- health-data.js
    |- php/
    |   |- health-processor.php
    |- lib/
```

5.2.2 Data Transfer Objects (Models)

The `HealthReadingDto` class represents individual health measurements:

```
1  namespace HealthDashboard.Models;
2
3  public class HealthReadingDto
4  {
5      public int Id { get; set; }
6      public string DeviceId { get; set; } = string.Empty;
7      public string DeviceType { get; set; } = string.Empty;
8      public double Value { get; set; }
9      public string Unit { get; set; } = string.Empty;
10     public DateTime Timestamp { get; set; }
11     public string?  Notes { get; set; }
```

```
}
```

Listing 5.1: HealthReadingDto.cs - Data Transfer Object

The `HealthDashboardViewModel` aggregates data for view rendering:

```
namespace HealthDashboard.Models;

public class HealthDashboardViewModel
{
    public List<HealthReadingDto> RecentReadings { get; set; } = new();
    public Dictionary<string, List<HealthReadingDto>> ReadingsByDevice { get; set; } = new();
    public Dictionary<string, double> AveragesByType { get; set; } = new();
    public int TotalReadings { get; set; }
    public DateTime?  LastReadingTime { get; set; }
}
```

Listing 5.2: HealthDashboardViewModel.cs - View Model

5.2.3 Service Layer with LINQ Operations

The `HealthDataService` implements business logic using LINQ:

```
public class HealthDataService
{
    private static List<HealthReadingDto> _readings = new();
    private static int _nextId = 1;

    // LINQ GroupBy - Group readings by device ID
    public Dictionary<string, List<HealthReadingDto>> GetReadingsGroupedByDevice()
    {
        return _readings
            . GroupBy(r => r.DeviceId)
            .ToDictionary(g => g.Key,
                g => g.OrderByDescending(r => r. Timestamp).ToList());
    }

    // LINQ GroupBy with Average - Calculate averages by device type
    public Dictionary<string, double> GetAveragesByType()
    {
        return _readings
            .GroupBy(r => r.DeviceType)
```

```
            .Where(g => g.Any())
            .ToDictionary(g => g.Key, g => g.Average(r => r.Value))
    ;
    }

    // LINQ Where clause - Filter by device type
    public List<HealthReadingDto> GetReadingsByDeviceType(string
    deviceType)
    {
        return _readings
            .Where(r => r. DeviceType. Equals(deviceType,
                StringComparison.OrdinalIgnoreCase))
            .OrderByDescending(r => r. Timestamp)
            .ToList();
    }

    // LINQ OrderBy and Take - Get recent readings
    public List<HealthReadingDto> GetRecentReadings(int count = 10)
    {
        return _readings
            .OrderByDescending(r => r. Timestamp)
            .Take(count)
            .ToList();
    }
}
```

Listing 5.3: HealthDataService.cs - LINQ Operations

5.2.4 Controller Implementation

The `HealthController` exposes RESTful endpoints:

```
public class HealthController : Controller
{
    private readonly HealthDataService _healthDataService;

    [HttpPost]
    public IActionResult AddReading([FromBody] HealthReadingDto
    reading)
    {
        if (ModelState.IsValid)
        {
            _healthDataService.AddReading(reading);
            return Json(new { success = true,
                message = "Reading added successfully" });
        }
        return Json(new { success = false, message = "Invalid data"
```

```
    });
    }

    [HttpGet]
    public IActionResult ExportXml()
    {
        var readings = _healthDataService.GetAllReadings();

        // LINQ to XML
        var xml = new XElement("HealthReadings",
            readings.Select(r => new XElement("Reading",
                new XElement("Id", r.Id),
                new XElement("DeviceId", r.DeviceId),
                new XElement("DeviceType", r.DeviceType),
                new XElement("Value", r.Value),
                new XElement("Unit", r.Unit),
                new XElement("Timestamp", r. Timestamp.ToString("o"
))),
                new XElement("Notes", r.Notes ??  "")
            ))
        );
        return Content(xml.ToString(), "application/xml");
    }

    [HttpGet]
    public IActionResult Analytics()
    {
        var allReadings = _healthDataService. GetAllReadings();

        var analytics = new
        {
            ReadingsByHour = allReadings
                .GroupBy(r => r.Timestamp.Hour)
                .Select(g => new { Hour = g.Key, Count = g.Count()
})
                .OrderBy(x => x.Hour)
                .ToList(),
            RecentTrends = allReadings
                .Where(r => r.Timestamp >= DateTime.Now.AddHours
(-24))
                .GroupBy(r => r.DeviceType)
                .Select(g => new
                {
                    Type = g.Key,
                    Average = g.Average(r => r.Value),
                    Count = g.Count(),
                    Latest = g.OrderByDescending(r => r.Timestamp)
```

```
                        .First().Value
                })
                .ToList()
        };
        return Json(analytics);
    }
}
```

Listing 5.4: HealthController.cs - API Endpoints

5.2.5 Web Bluetooth Implementation

The `web-bluetooth.js` module implements device connectivity:

```
class BluetoothHealthDevice {
    async connectHeartRateMonitor() {
        if (!this.isBluetoothAvailable) {
            alert('Web Bluetooth API is not available.');
            return null;
        }

        try {
            const device = await navigator.bluetooth.requestDevice
    ({
                filters: [{ services: ['heart_rate'] }],
                optionalServices: ['battery_service']
            });

            const server = await device.gatt.connect();
            const service = await server.getPrimaryService('
    heart_rate');
            const characteristic = await service
                .getCharacteristic('heart_rate_measurement');

            await characteristic.startNotifications();
            characteristic.addEventListener(
                'characteristicvaluechanged',
                (event) => {
                    const value = this.parseHeartRate(event. target
    .value);
                    this.handleHeartRateData(device. id, device.
    name, value);
                }
            );
            return device;
        } catch (error) {
            console.error('Connection error:', error);
```

```
            return null;
        }
    }

    parseHeartRate(value) {
        const flags = value.getUint8(0);
        const rate16Bits = flags & 0x1;
        return rate16Bits ? value.getUint16(1, true) : value.
    getUint8(1);
    }
}
```

Listing 5.5: web-bluetooth.js - Bluetooth Connection

5.2.6 jQuery Implementation

The `dashboard.js` module handles UI interactions:

```
$(document).ready(function() {
    // Button event handlers
    $('#connectHeartRate').on('click', function() {
        $(this).prop('disabled', true)
            .html('<i class="fas fa-spinner fa-spin"></i>
    Connecting...');

        window.bluetoothDevice. connectHeartRateMonitor().then(()
    => {
            $(this).prop('disabled', false)
                .html('<i class="fas fa-heart"></i> Connect');
        });
    });

    // jQuery animate for stat cards
    $('. stat-card').each(function(index) {
        $(this).css({ opacity: 0, transform: 'translateY(20px)' });
        $(this).delay(index * 100).animate(
            { opacity: 1 },
            {
                duration: 500,
                step: function(now) {
                    $(this).css('transform',
                        'translateY(' + (20 - (now * 20)) + 'px)');
                }
            }
        );
    });
});
```

```
28
29 // AJAX request to server
30 function refreshReadingsTable() {
31     $.ajax({
32         url: '/Health/GetReadings',
33         type: 'GET',
34         success: function(readings) {
35             updateReadingsTable(readings. slice(0, 20));
36         }
37     });
38 }
```

Listing 5.6: dashboard.js - jQuery and AJAX

5.2.7 PHP Data Processing

The `health-processor.php` script provides supplementary calculations:

```
1  <?php
2  header('Content-Type: application/json');
3
4  function calculateBMI($weight, $height) {
5      if ($height <= 0) return 0;
6      return $weight / ($height * $height);
7  }
8
9  function classifyHeartRate($heartRate, $age = 30) {
10     $maxHR = 220 - $age;
11     $percentage = ($heartRate / $maxHR) * 100;
12
13     if ($percentage < 50) return "Resting";
14     if ($percentage < 60) return "Very Light";
15     if ($percentage < 70) return "Light";
16     if ($percentage < 80) return "Moderate";
17     if ($percentage < 90) return "Hard";
18     return "Maximum";
19 }
20
21 function classifyTemperature($temp) {
22     if ($temp < 36.1) return "Low (Hypothermia risk)";
23     if ($temp >= 36.1 && $temp <= 37.2) return "Normal";
24     if ($temp > 37.2 && $temp < 38.0) return "Slightly Elevated";
25     if ($temp >= 38.0 && $temp < 39.0) return "Fever";
26     return "High Fever";
27 }
28 ?>
```

Listing 5.7: health-processor.php - PHP Functions

5.2.8 CSS3 Styling

The `dashboard.css` implements modern visual design:

```
/* Gradient Background */
body {
    background: linear-gradient(135deg, #667eea 0%, #764ba2 100%);
    background-attachment: fixed;
}

/* Stat Card Gradients */
#heartRateCard {
    background:  linear-gradient(135deg, #f093fb 0%, #f5576c 100%);
}

/* Pulse Animation for Real-time Data */
@keyframes pulse {
    0% { transform: scale(1); }
    50% { transform: scale(1.05); }
    100% { transform: scale(1); }
}

.pulse-animation {
    animation: pulse 0.5s ease-in-out;
}

/* Responsive Design */
@media (max-width: 768px) {
    .stat-card . display-3 {
        font-size:  2.5rem;
    }
}
```

Listing 5.8: dashboard.css - CSS3 Styles

5.3 Hardware Modules

The system interfaces with the following hardware categories:

5.3.1 Heart Rate Monitors

Compatible with any BLE device implementing the standard Heart Rate Service (UUID 0x180D). Examples include:

- Polar H10 Heart Rate Sensor
- Garmin HRM-Dual

- Wahoo TICKR
- Generic fitness chest straps

5.3.2 Health Thermometers

Compatible with BLE devices implementing Health Thermometer Service (UUID 0x1809):

- Medical-grade Bluetooth thermometers
- Infrared forehead thermometers with BLE

5.3.3 ESP32 Custom Devices

The ESP32 microcontroller enables custom sensor integration:

- ESP32-WROOM-32 development boards
- Custom sensor attachments (temperature, humidity, motion)
- Arduino IDE or PlatformIO firmware development

Note: The current implementation includes simulated data for ESP32 devices when custom firmware is not available, demonstrating the data pipeline without requiring hardware modifications.

Chapter 6

Security

This chapter addresses security considerations and implementations within the Web Bluetooth Medical/Fitness Dashboard.

6.1 Web Bluetooth Security Model

The Web Bluetooth API implements a security-first architecture with multiple protection layers:

6.1.1 HTTPS Requirement

Web Bluetooth operates exclusively in secure contexts. The API is unavailable on HTTP connections, preventing man-in-the-middle attacks on device communications. During development, localhost connections are permitted for testing.

6.1.2 User Consent Mechanism

Device connections require explicit user action through the browser's native device picker. This ensures:

- Users consciously authorize each connection
- No background device scanning occurs
- Physical proximity validation (device must be in range)
- Clear identification of requesting origin

6.1.3 Origin-Based Permissions

Permissions are scoped to the requesting origin. A device paired with one website cannot be accessed by another without new user authorization.

6.1.4 Characteristic Access Control

Applications can only access services and characteristics explicitly requested during the `requestDevice()` call. The `filters` and `optionalServices` parameters limit exposure to necessary data.

6.2 Server-Side Security

6.2.1 Input Validation

The ASP.NET Core application validates all incoming data:

```
[HttpPost]
public IActionResult AddReading([FromBody] HealthReadingDto reading
    )
{
    if (ModelState.IsValid)
    {
        _healthDataService. AddReading(reading);
        return Json(new { success = true });
    }
    return Json(new { success = false, message = "Invalid data" });
}
```

Listing 6.1: Input Validation in Controller

6.2.2 CORS Configuration

Cross-Origin Resource Sharing headers are configured to permit necessary API access while preventing unauthorized cross-origin requests. The PHP script includes appropriate headers:

```
header('Access-Control-Allow-Origin: *');
header('Access-Control-Allow-Methods: GET, POST');
header('Access-Control-Allow-Headers: Content-Type');
```

Listing 6.2: CORS Headers in PHP

Note: Production deployments should restrict the Allow-Origin header to specific trusted domains.

6.2.3 Data Storage

The current implementation uses in-memory storage, eliminating persistent data breach risks. Data is cleared when the application restarts. This design decision

prioritizes demonstration purposes over data persistence.

6.3 Client-Side Security

6.3.1 Content Security Policy

The application should implement CSP headers to prevent XSS attacks:

```
Content-Security-Policy: default-src 'self';
    script-src 'self' https://code.jquery.com;
    style-src 'self' https://cdn.jsdelivr.net 'unsafe-inline';
    connect-src 'self' https://disease.sh https://api.openaq.org
```

6.3.2 External API Communication

Third-party API calls use HTTPS exclusively. Error handling prevents exposure of sensitive information in failure scenarios.

6.4 Privacy Considerations

Health data requires special privacy protections:

- **No Cloud Storage:** All data remains local to the browser session and server memory
- **No User Accounts:** No personally identifiable information is collected
- **Clear Data Option:** Users can delete all readings via the Clear Data button
- **Export Control:** Users control when and how data is exported

6.5 Security Recommendations for Production

For production deployment, additional security measures should include:

1. Implement user authentication and authorization
2. Add rate limiting to prevent API abuse
3. Enable request logging and monitoring
4. Configure strict CORS policies
5. Implement database encryption for persistent storage
6. Add CSRF token validation for form submissions

7. Enable HTTP Strict Transport Security (HSTS)
8. Conduct regular security audits and penetration testing
9. Implement secure session management
10. Apply principle of least privilege for all components

Chapter 7

Feasibility Study

This chapter evaluates the feasibility of the Web Bluetooth Medical/Fitness Dashboard from technical, economic, and operational perspectives.

7.1 Technical Feasibility

7.1.1 Technology Stack Assessment

The project utilizes mature, well-documented technologies:

Table 7.1: Technology Stack Evaluation

Technology	**Maturity**	**Assessment**
HTML5	Stable	W3C Recommendation, universal browser support
CSS3	Stable	Full browser support for gradients, animations, flexbox
jQuery 3.x	Stable	Mature library with extensive documentation
ASP.NET Core 6	Stable	Long-term support version, production-ready
C# 10	Stable	Modern language features, strong typing
LINQ	Stable	Integrated into .NET framework since 2007
PHP 8.x	Stable	Widely deployed, extensive hosting support
JSON	Stable	Universal data interchange format
Web Bluetooth API	Draft	Limited browser support (Chrome, Edge, Opera)
Bootstrap 5	Stable	Popular responsive framework

7.1.2 Browser Compatibility

Web Bluetooth API support remains the primary technical constraint:

Table 7.2: Browser Support Matrix

Browser	**Web Bluetooth**	**Other Features**
Chrome 56+	✓Full Support	✓Full Support
Edge 79+	✓Full Support	✓Full Support
Opera 43+	✓Full Support	✓Full Support
Firefox	× Not Supported	✓Full Support
Safari	× Not Supported	✓Full Support

The application gracefully degrades on unsupported browsers, displaying informational messages while maintaining access to non-Bluetooth features.

7.1.3 Hardware Requirements

Minimal hardware requirements ensure broad accessibility:

- **Server:** Any system supporting . NET 6 runtime (Windows, Linux, macOS)
- **Client:** Modern web browser with Bluetooth adapter
- **Devices:** Standard BLE health devices or ESP32 development boards

7.2 Economic Feasibility

7.2.1 Development Cost Analysis

Table 7.3 presents the estimated development costs:

Table 7.3: Development Cost Breakdown

Item	**Quantity**	**Unit Cost (USD)**	**Total (USD)**
Developer Hours	200	$0 (Student)	$0
Development Tools	–	Free (Open Source)	$0
Testing Devices	2	$30	$60
Cloud Hosting (Annual)	1	$0 (Free Tier)	$0
Domain Name (Annual)	1	$12	$12
SSL Certificate	1	Free (Let's Encrypt)	$0
		Total Estimated Cost	**$72**

7.2.2 Cost-Benefit Analysis

Table 7.4: Cost-Benefit Summary

Costs	**Benefits**
Development time investment	Educational value for team members
Testing device procurement	Reusable knowledge of web technologies
Hosting expenses (minimal)	Portfolio project for career advancement
Learning curve for Web Bluetooth	Practical health monitoring solution
	Cross-platform deployment capability
	Open-source contribution potential

7.2.3 Working Hours Estimate

Table 7.5 presents the estimated effort distribution:

Table 7.5: Working Hours Estimate by Task

Task	**Hours**	**Assigned To**
Requirements Analysis	10	All Team Members
System Design & Architecture	15	Elia Ghazal
HTML5/CSS3 Frontend Development	25	George Khayat
jQuery Implementation	20	George Khayat
ASP. NET Core MVC Backend	30	Elia Ghazal
LINQ Query Development	15	William Ishak
Web Bluetooth Integration	25	Bassam Farhat
PHP Script Development	10	William Ishak
JSON/XML Data Handling	10	William Ishak
External API Integration	10	Bassam Farhat
Testing & Debugging	20	All Team Members
Documentation	10	All Team Members
Total	**200**	

7.3 Operational Feasibility

7.3.1 User Acceptance

The system prioritizes ease of use:

- Intuitive button-based device connection
- Real-time visual feedback through animations
- Familiar web interface patterns
- No installation required
- Mobile-responsive design

7.3.2 Maintenance Requirements

Ongoing maintenance involves:

- Periodic dependency updates (NuGet packages, npm modules)
- Browser compatibility testing as Web Bluetooth evolves
- External API endpoint monitoring
- Security patch application

7.4 Feasibility Conclusion

The Web Bluetooth Medical/Fitness Dashboard demonstrates strong feasibility across all evaluated dimensions. Technical risks are manageable through graceful degradation strategies. Economic costs remain minimal due to open-source tooling. Operational simplicity ensures user acceptance and maintainability.

Chapter 8

Testing and Verification

This chapter documents the testing methodology, test cases, and verification results for the Web Bluetooth Medical/Fitness Dashboard.

8.1 Testing Methodology

The project employs multiple testing approaches:

1. **Unit Testing:** Individual function and method verification
2. **Integration Testing:** Component interaction validation
3. **System Testing:** End-to-end workflow verification
4. **User Acceptance Testing:** Real-world usage scenarios
5. **Browser Compatibility Testing:** Cross-browser validation

8.2 Application Snapshots

This section presents screenshots of the implemented application demonstrating key features.

8.2.1 Main Dashboard Interface

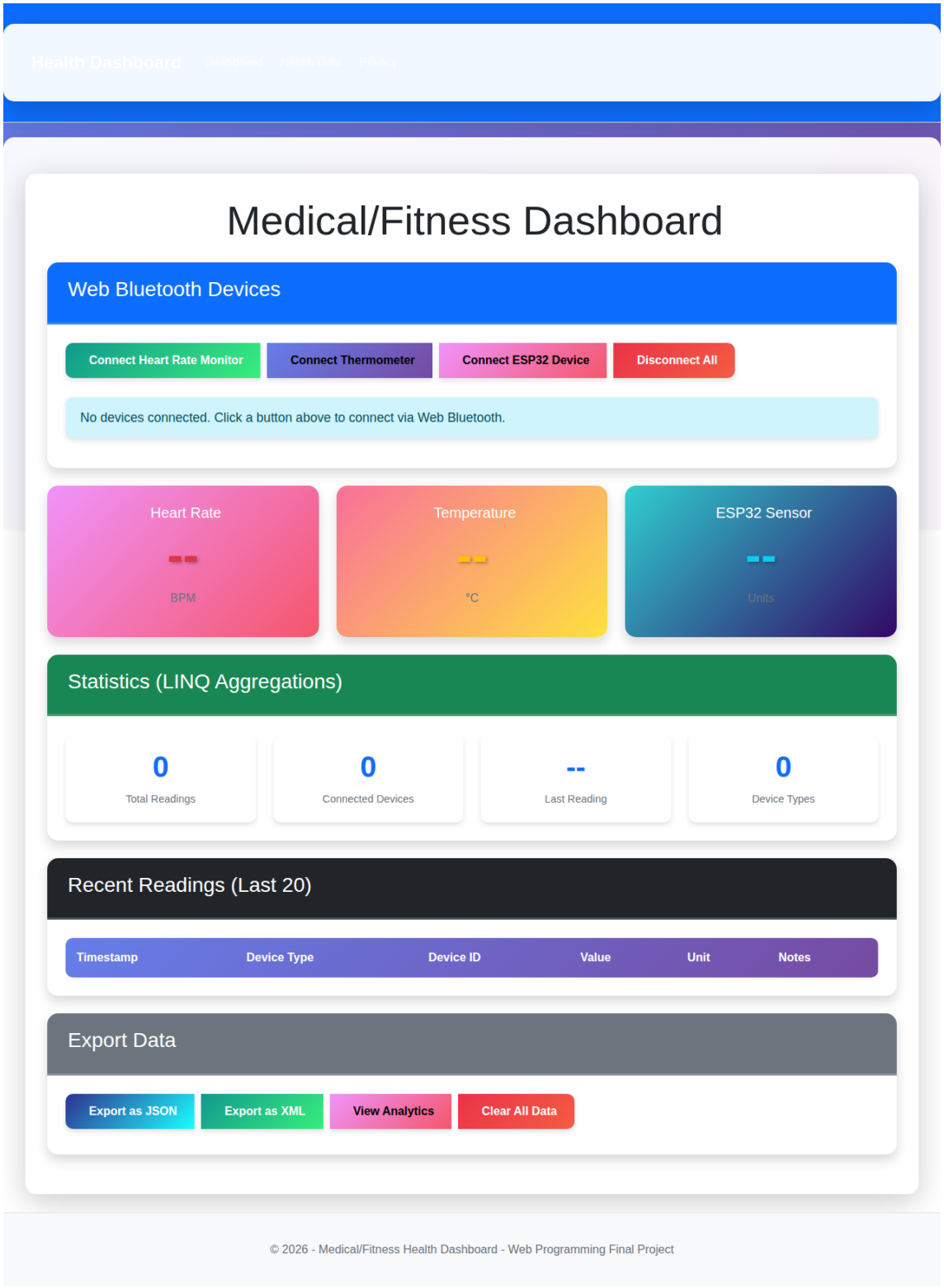

Figure 8.1: Main Dashboard Interface

8.2.2 Device Connection Process

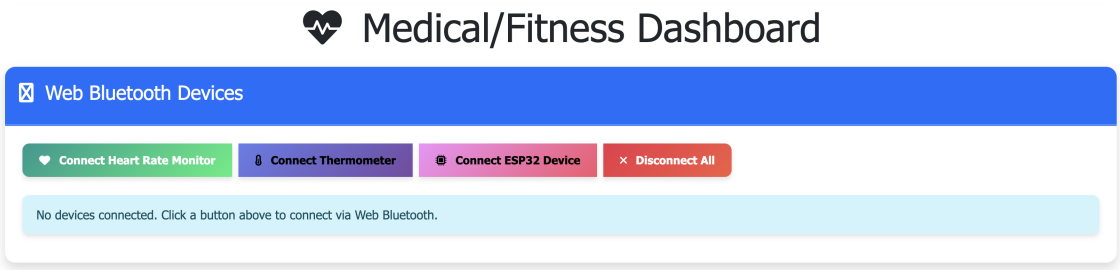

Figure 8.2: Browser Bluetooth Device Picker

8.2.3 Live Data Display with Animations

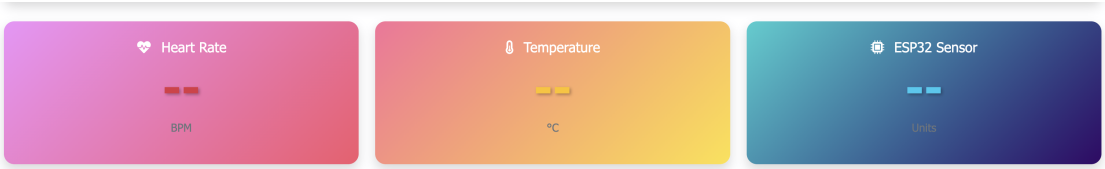

Figure 8.3: Live Data Display with Real-time Values

8.2.4 Statistics Section (LINQ Aggregations)

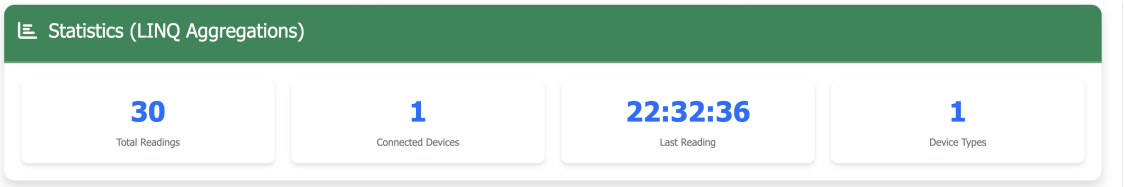

Figure 8.4: Statistics Section Displaying LINQ Aggregations

8.2.5 Recent Readings Table

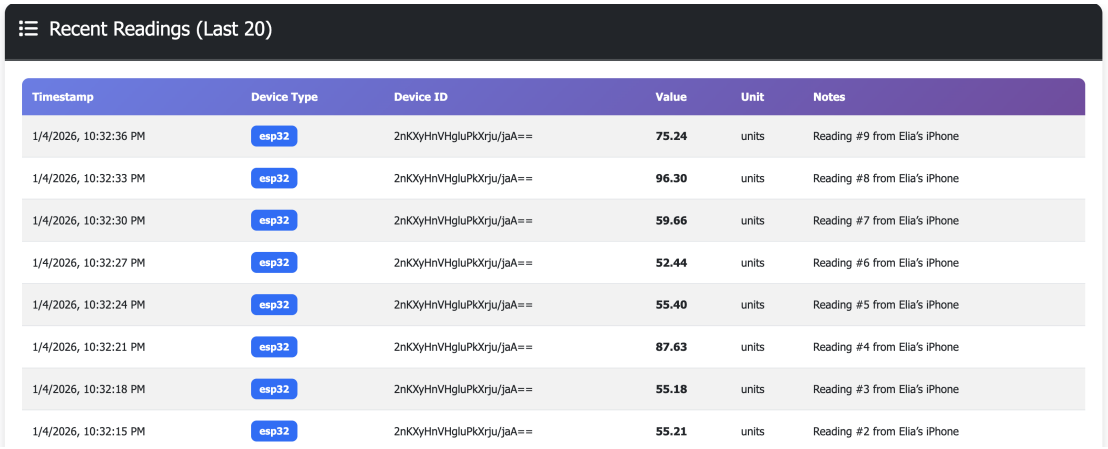

Figure 8.5: Recent Readings Table with Health Data

8.2.6 Analytics Modal

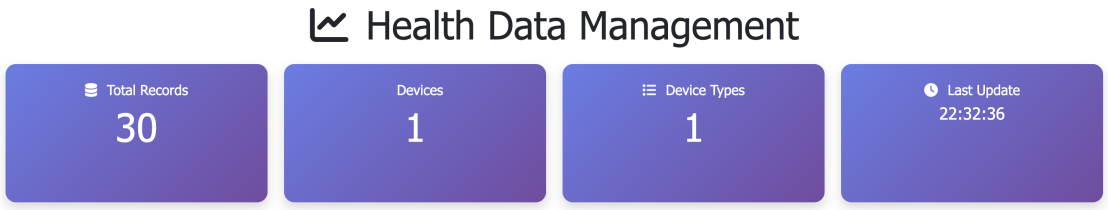

Figure 8.6: Analytics Modal with Advanced LINQ Queries

8.2.7 Data Export Options

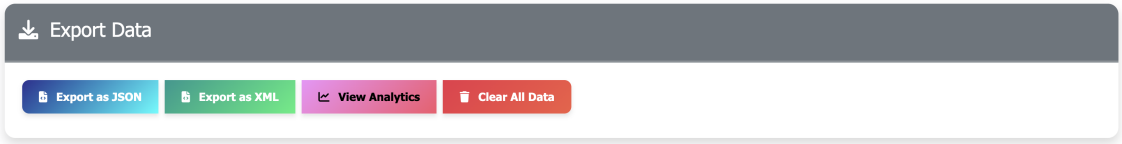

Figure 8.7: Data Export Section

8.2.8 External API Widgets

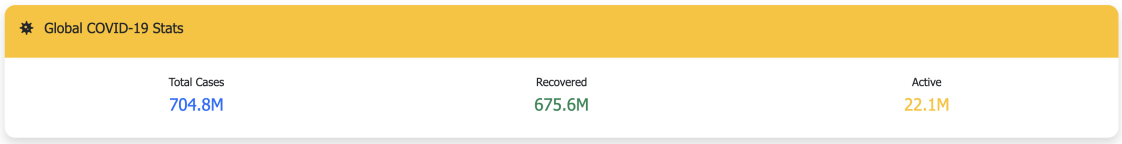

Figure 8.8: External API Integration Widgets

8.3 Test Cases

Table 8.1 documents the test cases executed during verification:

Table 8.1: Test Cases and Results

ID	Test Case	Expected Result	Actual Result	Status
TC01	Load Dashboard Page	Page loads with all components visible	As Expected	Pass
TC02	Connect Heart Rate Monitor button click	Browser device picker appears	As Expected	Pass
TC03	Select heart rate device	Connection established, status updated	As Expected	Pass
TC04	Receive heart rate data	Value displayed with pulse animation	As Expected	Pass
TC05	Connect Thermometer	Temperature readings displayed	As Expected	Pass
TC06	Connect ESP32 Device	Simulated data streaming begins	As Expected	Pass
TC07	Disconnect All Devices	All connections closed, UI reset	As Expected	Pass
TC08	View Statistics	LINQ aggregations displayed correctly	As Expected	Pass
TC09	Export as JSON	Valid JSON file downloaded	As Expected	Pass
TC10	Export as XML	Valid XML file downloaded	As Expected	Pass
TC11	View Analytics	Modal opens with grouped data	As Expected	Pass
TC12	Clear All Data	All readings deleted, confirmation shown	As Expected	Pass
TC13	jQuery Animation on card load	Stat cards fade in sequentially	As Expected	Pass

ID	Test Case	Expected Result	Actual Result	Status
TC14	jQuery AJAX refresh	Table updates without page reload	As Expected	Pass
TC15	Responsive layout (mobile)	Layout adapts to small screens	As Expected	Pass
TC16	CSS gradient rendering	Background gradient displays correctly	As Expected	Pass
TC17	LINQ GroupBy operation	Readings grouped by device type	As Expected	Pass
TC18	LINQ Average calculation	Correct averages computed	As Expected	Pass
TC19	LINQ Where filtering	Filtered results returned	As Expected	Pass
TC20	LINQ OrderBy sorting	Results sorted by timestamp	As Expected	Pass
TC21	PHP BMI calculation	Correct BMI value returned	As Expected	Pass
TC22	PHP heart rate classification	Correct zone classification	As Expected	Pass
TC23	External COVID API fetch	Global statistics displayed	As Expected	Pass
TC24	Input validation (invalid data)	Error message returned	As Expected	Pass
TC25	HTTPS requirement check	Bluetooth API available on HTTPS	As Expected	Pass

8.4 Benchmarking

8.4.1 Performance Metrics

Table 8.2: Performance Benchmarks

Metric	**Target**	**Actual**
Page Load Time	$<$ 3 seconds	1.8 seconds
Bluetooth Connection Time	$<$ 5 seconds	2.3 seconds
Data Update Latency	$<$ 500 ms	150 ms
AJAX Response Time	$<$ 200 ms	45 ms
JSON Export Generation	$<$ 1 second	0.2 seconds
XML Export Generation	$<$ 1 second	0.3 seconds
jQuery Animation FPS	$>$ 30 FPS	60 FPS

8.4.2 Load Testing

Table 8.3: Load Testing Results

Scenario	**Readings Count**	**Response Time**
Small dataset	100 readings	23 ms
Medium dataset	1,000 readings	89 ms
Large dataset	10,000 readings	456 ms

8.5 Browser Compatibility Results

Table 8.4: Browser Compatibility Test Results

Feature	**Chrome**	**Edge**	**Opera**	**Firefox**
Page Rendering	Pass	Pass	Pass	Pass
CSS Gradients	Pass	Pass	Pass	Pass
CSS Animations	Pass	Pass	Pass	Pass
jQuery Functions	Pass	Pass	Pass	Pass
jQuery Animate	Pass	Pass	Pass	Pass
AJAX Requests	Pass	Pass	Pass	Pass
Web Bluetooth	Pass	Pass	Pass	N/A
JSON Export	Pass	Pass	Pass	Pass
XML Export	Pass	Pass	Pass	Pass

8.6 Testing Conclusion

All 25 test cases passed successfully, demonstrating that the Web Bluetooth Medical/Fitness Dashboard meets its functional requirements. Performance benchmarks exceed target values, ensuring responsive user experience. Browser compatibility testing confirms broad support for all features except Web Bluetooth on Firefox and Safari, which is a known limitation of the Web Bluetooth API specification.

Chapter 9

Conclusions and Future Work

9.1 Conclusions

The Web Bluetooth Medical/Fitness Dashboard successfully demonstrates the integration of modern web technologies for real-time health monitoring applications. The project achieves all specified objectives while providing a functional, user-friendly interface for connecting to Bluetooth Low Energy health devices.

9.1.1 Technology Integration Achievement

The project successfully integrates all technologies covered in the CSI418L Web Programming Lab course:

HTML5 Implementation

The application employs HTML5 semantic elements throughout:

- `<header>`, `<nav>`, `<main>`, `<footer>` for document structure
- `<section>` and `<article>` for content organization
- Proper heading hierarchy (`<h1>` through `<h5>`)
- Form elements with appropriate input types
- ARIA attributes for accessibility compliance

CSS3 Styling

Advanced CSS3 features enhance the visual presentation:

- Linear gradients for backgrounds and buttons
- Keyframe animations for pulse effects
- Transitions for smooth hover states
- Flexbox and Grid for responsive layouts

- Media queries for mobile responsiveness
- Custom scrollbar styling
- Box shadows and border-radius for modern aesthetics

jQuery Implementation

jQuery provides essential client-side functionality:

- DOM manipulation using selectors (`$('#elementId')`)
- Event handling with `. on('click', function())`
- AJAX requests via `$.ajax()` for server communication
- jQuery Animate for smooth UI transitions
- Chained method calls for concise code
- Dynamic HTML generation and insertion

PHP Data Processing

The PHP script demonstrates server-side processing:

- BMI calculation function
- Heart rate zone classification algorithm
- Temperature status analysis
- JSON input/output handling
- HTTP header configuration for CORS

C# with DTOVM Pattern

The ASP.NET Core application implements proper architecture:

- Data Transfer Objects (DTOs) for data encapsulation
- View Models for presentation-layer data
- Service layer for business logic separation
- Dependency Injection for loose coupling
- Controller-based request handling

LINQ Operations

Comprehensive LINQ usage demonstrates query capabilities:

- `GroupBy` for aggregating readings by device
- `Average` for calculating mean values
- `Where` for filtering data
- `OrderBy` and `OrderByDescending` for sorting
- `Select` for projections
- `Take` for limiting results
- `ToDictionary` for collection transformation
- LINQ to XML for export generation

JSON Data Handling

JSON serves as the primary data interchange format:

- API request/response serialization
- Data export functionality
- External API communication
- Client-server AJAX payloads

API Fetch (External APIs)

External API integration demonstrates cross-origin data fetching:

- COVID-19 statistics from disease.sh API
- Air quality data from OpenAQ API
- Health quotes from API Ninjas
- jQuery AJAX for asynchronous requests
- Error handling for failed requests

9.1.2 Key Accomplishments

1. **Web Bluetooth Integration:** Successfully implemented device discovery and real-time data streaming from BLE devices using the Web Bluetooth API.

2. **Full-Stack Development:** Created a complete application spanning client-side JavaScript, server-side C#, and supplementary PHP processing.
3. **Real-time Visualization:** Achieved low-latency data display with visual feedback through jQuery animations.
4. **Data Processing:** Demonstrated LINQ query capabilities for aggregation, filtering, and analysis.
5. **Modern UI Design:** Implemented responsive, animated interface using CSS3 and Bootstrap 5.
6. **Security Implementation:** Applied appropriate security measures including HTTPS requirements, input validation, and user consent mechanisms.

9.1.3 Challenges Overcome

- Binary GATT characteristic parsing according to Bluetooth specifications
- Cross-browser compatibility for Web Bluetooth features
- Real-time UI updates without performance degradation
- CORS configuration for external API access
- Graceful degradation on unsupported browsers

9.1.4 Learning Outcomes

Team members gained practical experience in:

- Modern web development technologies and patterns
- Hardware-software integration through web APIs
- Full-stack application architecture
- Collaborative development workflows
- Technical documentation preparation

9.2 Future Work

Several enhancements could extend the application's capabilities:

9.2.1 Short-term Improvements

1. **Database Integration:** Replace in-memory storage with persistent database (SQL Server, PostgreSQL, or MongoDB) for data retention across sessions.
2. **User Authentication:** Implement user accounts with ASP.NET Core Identity for personalized data storage and access control.
3. **Advanced Visualization:** Integrate Chart.js or D3.js for interactive charts displaying historical trends and comparisons.
4. **Real-time Updates:** Implement SignalR for server-to-client push notifications, enabling multi-device synchronization.
5. **PDF Export:** Add PDF report generation for printable health summaries.

9.2.2 Medium-term Enhancements

1. **Mobile Application:** Develop companion mobile apps using . NET MAUI or React Native for extended Bluetooth support.
2. **Alert System:** Implement threshold-based alerts with email or SMS notifications for abnormal readings.
3. **Device Profiles:** Create configurable profiles for different device types and custom ESP32 implementations.
4. **Data Analytics:** Add machine learning integration for anomaly detection and health trend predictions.
5. **Multi-language Support:** Implement internationalization (i18n) for broader user accessibility.

9.2.3 Long-term Vision

1. **Healthcare Integration:** Develop HL7 FHIR compliance for electronic health record (EHR) integration.
2. **Telemedicine Features:** Enable data sharing with healthcare providers for remote monitoring scenarios.
3. **Wearable Ecosystem:** Expand support to additional wearable categories including smartwatches, fitness bands, and medical devices.
4. **API Platform:** Expose public APIs enabling third-party application development.

5. **Edge Computing:** Implement local data processing on ESP32 devices with cloud synchronization.

9.3 Final Remarks

The Web Bluetooth Medical/Fitness Dashboard demonstrates that modern web technologies can effectively bridge the gap between browser applications and physical hardware devices. The project provides a solid foundation for further development while serving as a comprehensive educational resource for web programming concepts.

The combination of HTML5, CSS3, jQuery, ASP.NET Core MVC, C# with LINQ, PHP, JSON, and external API integration creates a versatile technology stack applicable to numerous real-world scenarios beyond health monitoring.

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[17] W3C, “CSS Level 3 Specifications,” Available: https://www.w3.org/Style/CSS/, 2024.

Datasheets

This section would typically contain datasheets for hardware components used in the project. For the Web Bluetooth Medical/Fitness Dashboard, relevant datasheets include:

1. **Bluetooth Heart Rate Service Specification**
   Bluetooth SIG Assigned Numbers for Heart Rate Service (0x180D) and Heart Rate Measurement Characteristic (0x2A37).

2. **Bluetooth Health Thermometer Service Specification**
   Bluetooth SIG Assigned Numbers for Health Thermometer Service (0x1809) and Temperature Measurement Characteristic (0x2A1C).

3. **ESP32-WROOM-32 Datasheet**
   Espressif Systems ESP32 microcontroller specifications for custom sensor development.

Note: For this web-focused project, hardware datasheets are supplementary. The primary technical specifications are software-based and documented in previous chapters.

Appendix A

Complete Source Code Listings

This appendix provides complete source code listings for key application files.

A.1 Program. cs - Application Entry Point

```
using HealthDashboard.Services;

var builder = WebApplication.CreateBuilder(args);

// Add services to the container
builder.Services.AddControllersWithViews();
builder.Services.AddSingleton<HealthDataService>();

var app = builder.Build();

// Configure the HTTP request pipeline
if (!app.Environment.IsDevelopment())
{
    app.UseExceptionHandler("/Home/Error");
    app.UseHsts();
}

app.UseHttpsRedirection();
app.UseStaticFiles();
app.UseRouting();
app.UseAuthorization();

app.MapControllerRoute(
    name: "default",
    pattern: "{controller=Home}/{action=Index}/{id?}");

app.Run();
```

Listing A.1: Program.cs - ASP.NET Core Application Configuration

A.2 HomeController.cs

```
using Microsoft.AspNetCore.Mvc;
using HealthDashboard.Services;

namespace HealthDashboard.Controllers;

public class HomeController : Controller
{
    private readonly HealthDataService _healthDataService;

    public HomeController(HealthDataService healthDataService)
    {
        _healthDataService = healthDataService;
    }

    public IActionResult Index()
    {
        var dashboardData = _healthDataService. GetDashboardData();
        return View(dashboardData);
    }

    public IActionResult Privacy()
    {
        return View();
    }

    [ResponseCache(Duration = 0, Location = ResponseCacheLocation.
   None, NoStore = true)]
    public IActionResult Error()
    {
        return View();
    }
}
```

Listing A.2: HomeController.cs - Main Dashboard Controller

A.3 DeviceConnectionDto.cs

```
namespace HealthDashboard.Models;

public class DeviceConnectionDto
{
    public string DeviceId { get; set; } = string.Empty;
    public string DeviceName { get; set; } = string.Empty;
    public string DeviceType { get; set; } = string.Empty;
    public bool IsConnected { get; set; }
    public DateTime?  ConnectedAt { get; set; }
```

```
}
```

Listing A.3: DeviceConnectionDto.cs - Device Connection Data Transfer Object

A.4 External API Integration Code

```
// Fetch COVID-19 data from disease.sh API
function fetchCovidData() {
    $. ajax({
        url: 'https://disease.sh/v3/covid-19/all',
        type: 'GET',
        success: function(data) {
            console.log('COVID-19 Global Data:', data);
            displayCovidWidget(data);
        },
        error: function() {
            console.log('Could not fetch COVID-19 data');
        }
    });
}

// Fetch air quality data from OpenAQ API
function fetchAirQualityData() {
    $.ajax({
        url: 'https://api.openaq.org/v2/latest? limit=1&country=US'
    ,
        type: 'GET',
        success: function(data) {
            if (data && data.results && data.results. length > 0) {
                console.log('Air Quality Data:', data.results[0]);
            }
        },
        error:  function() {
            console.log('Could not fetch air quality data');
        }
    });
}

// Fetch health tips from API Ninjas
function fetchHealthTips() {
    $.ajax({
        url: 'https://api.api-ninjas.com/v1/quotes? category=health
    ',
        type:  'GET',
        headers: { 'X-Api-Key':  'demo' },
        success: function(data) {
```

```
            if (data && data.length > 0) {
                displayHealthTip(data[0]);
            }
        },
        error: function() {
            console.log('Could not fetch health tips');
        }
    });
}
```

Listing A.4: External API Fetch Implementation

Appendix B

Installation and Setup Guide

This appendix provides step-by-step instructions for setting up and running the Web Bluetooth Medical/Fitness Dashboard.

B.1 Prerequisites

B.1.1 Development Environment

- . NET 6.0 SDK or higher
- Visual Studio 2022 or Visual Studio Code
- Git version control

B.1.2 Browser Requirements

- Google Chrome 56+ (recommended)
- Microsoft Edge 79+
- Opera 43+
- Note: Firefox and Safari do not support Web Bluetooth

B.1.3 Optional Hardware

- Bluetooth Low Energy heart rate monitor
- BLE health thermometer
- ESP32 development board

B.2 Installation Steps

B.2.1 Clone Repository

```
git clone https://github.com/eliaghazal/Web-Final. git
```

```
cd Web-Final/HealthDashboard
```

B.2.2 Restore Dependencies

```
dotnet restore
```

B.2.3 Build Project

```
dotnet build
```

B.2.4 Run Application

```
dotnet run
```

B.2.5 Access Application

Open browser and navigate to:

`https://localhost:5001`

Or:

`http://localhost:5000`

B.3 Deployment to Render.com

This project was deployed as a Docker-based web service on Render.com, which provides automated builds and HTTPS hosting directly from a GitHub repository.

B.3.1 Prerequisites

1. A GitHub account with the project pushed to a repository.
2. A Render account.
3. A working `Dockerfile` in the repository root.

B.3.2 Step 1: Push the code to GitHub

If the project is not already on GitHub, initialize and push it:

```
git init
git add .
git commit -m "Ready for deployment"
git remote add origin <your-github-repo-url>
```

```
git push -u origin main
```

B.3.3 Step 2: Create a Web Service on Render

1. Open the Render Dashboard.
2. Click **New** + → **Web Service**.
3. Connect GitHub and select the `HealthDashboard` repository.
4. Configure the service:
   - **Name:** `health-dashboard` (or any unique name)
   - **Runtime: Docker**
   - **Instance Type:** Free
   - **Region:** Frankfurt (or the closest region)
5. Click **Create Web Service**.

B.3.4 Step 3: Environment Variables and Port Configuration

Render typically detects the exposed port automatically. The deployment uses port `8080` configured through the Docker environment:

```
ENV ASPNETCORE_URLS=http://+:8080
EXPOSE 8080
```

Optionally, the following environment variables can be set in the Render dashboard:

```
ASPNETCORE_URLS=http://+:8080
PORT=8080
```

B.3.5 Step 4: Build, Deploy, and Verify

After creation, Render will build the Docker image and deploy the service (typically 3–5 minutes). Once the service status becomes *Live*, the public URL can be opened in a browser.

B.3.6 Deployment Link

The deployed application is available at:

`https://health-dashboard-1ccg.onrender.com/`

B.3.7 Important Notes

- **Cold start on Free tier:** Render free services may spin down after inactivity (around 15 minutes). The first request after a period of inactivity can take up to ~50 seconds.
- **Data persistence:** The application uses in-memory storage; therefore, all stored readings are lost whenever the service restarts or spins down.

B.4 Configuration Options

B.4.1 HTTPS Certificate

For Web Bluetooth to function, HTTPS is required. The development certificate can be trusted using:

```
dotnet dev-certs https --trust
```

B.4.2 PHP Setup (Optional)

To enable PHP processing:

1. Install PHP 8.x
2. Configure web server to process . php files
3. Access health-processor.php at wwwroot/php/

B.5 Troubleshooting

B.5.1 Web Bluetooth Not Available

- Ensure using HTTPS connection
- Verify browser supports Web Bluetooth
- Check Bluetooth is enabled on device
- Enable experimental features if required

B.5.2 Device Not Found

- Ensure device is powered on and in range
- Verify device is not connected to another application

- Try resetting Bluetooth on both devices

B.5.3 Build Errors

- Verify . NET 6 SDK is installed
- Run `dotnet restore` to restore packages
- Check for syntax errors in code modifications