MINISTRY OF EDUCATION

TECHNICAL UNIVERSITY
OF CLUJ-NAPOCA, ROMANIA

FACULTY OF AUTOMATION AND COMPUTER SCIENCE

CTPentru Toti

SEMESTER PROJECT

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1 Introduction

1.1 Project context

Public transportation has and always will be an important feature in modern life, that people will continue to use and rely on throughout day-to-day life. This necessity becomes especially important when we consider the increasing traffic in big cities, the search for a parking spot and the costs associated with these two inconveniences. A good public transportation system is mandatory to become a solution for these problems, but following a schedule is no easy task due to the intricate dependencies and variables that play a role during even a simple trip between two fixed places. Therefore, CTPentru Toti aims to assist the users by providing a real-time solution to accessing the bus locations and estimate time of arrival, to minimize the time loss and increase efficiency.

1.2 Objectives

The primary objectives of this project were established with the intent of enhancing the urban mobility experience in Cluj-Napoca through technological intervention. These objectives are outlined as follows:

- Develop a Real-time Vehicle Tracking System: Implement an application capable of tracking public transport vehicles in real-time, using data from the Tranzy API. This system aims to provide users with up-to-the-minute information about vehicle locations, aiding in efficient travel planning.
- User-Friendly Interface for Easy Access: Design an intuitive and accessible user interface that simplifies the process of accessing transport information. The interface should be navigable and understandable for a diverse user base, regardless of their technical proficiency.
- Integration with Google Maps API: Seamlessly integrate the application with Google Maps to offer users comprehensive navigational assistance, including route mapping and geospatial data visualization.
- Address Practical Commuting Challenges: The application seeks to solve real-world problems faced by commuters, such as estimating arrival times and identifying the most convenient routes.
- Promote Public Transport Usage: By providing reliable and easily accessible information, the project aims to encourage more residents and visitors to utilize public transport, thereby contributing to environmental sustainability and reduced traffic congestion.

1.3 Specifications

Real-Time Data Retrieval: The application is designed to fetch and display real-time data about public transport vehicles. This includes:

Current Location: Showcasing the real-time position of each vehicle on the map.

Route Information: Detailing the route each vehicle is following.

User-Centric Design: The interface focuses on usability, featuring:

Clear Navigation: Intuitive layout that users can easily interact with.

Readable Displays: Information presented in a legible and comprehensible manner.

Responsive Design: Compatibility with various devices, ensuring a seamless experience on smartphones, tablets, and desktop computers.

Efficiency: Key performance attributes include:

Low Latency: Swift data retrieval and updates.

Optimized Display: Quick rendering of information on the user interface.

Data Protection: Implementing robust security measures to safeguard user data.

Consistent Performance: Ensuring the application's reliability through various conditions.

Testing and Validation: Comprehensive testing strategies, including:

Usability Testing: Assessing the application's user experience.

External Dependencies: Addressing the reliance on external APIs for data.

Data Accuracy: Ensuring the correctness of real-time information.

Geographical Coverage: The application is currently limited to Cluj-Napoca.

2 Bibliographic research

Centrul de Transport Public Cluj-Napoca. (n.d.). TranZy: The Application Enhancing Urban Mobility. Retrieved January 16, 2024, from https://ctpcj.ro/index.php/ro/despre-noi/stiri/tranzy-aplicatia-care-eficientizeaza-mobilitatea-urbana/1378.

This bibliographical entry refers to the webpage titled "TranZy: The Application Enhancing Urban Mobility" from the website of Centrul de Transport Public Cluj-Napoca. We used the Tranzy API for displaying the information about routes, buses and bus stops.

Cluj-Napoca Public Transport Center. (n.d.). Homepage. Retrieved January 16, 2024, from https://ctpcj.ro/index.php/ro/

This is a bibliographical summary for the homepage of the "Cluj-Napoca Public Transport Center" website. CTP is the Public Transport Provider inside Cluj-Napoca and we require their authorization for building this project.

FlashWebIT. (n.d.). cfr-iris-scraper: CFR Iris Scraper GitHub Repository. Retrieved January 16, 2024, from https://github.com/FlashWebIT/cfr-iris-scraper/tree/master

This bibliographical entry references the GitHub repository titled "cfr-iris-scraper" by FlashWebIT. The application was built to show the trains around Romania updated every couple of minutes. The code provided in this application has served as a reference for our project.

3 Implementation

3.1 Analysis and Design:

The project's problem-solving approach centered on interpreting GPS data from public transport vehicles and efficiently processing real-time information. This included the development of specialized algorithms and the application of robust data handling techniques. Key methods for route optimization and performance enhancement were integral, focusing on optimizing vehicle routes and speeding up response times. For instance, the project utilized advanced calculations and optimization models to ensure efficient data processing and minimal latency.

Materials and procedures involved the integration and customization of the Google Maps API, highlighting how the project leveraged this powerful tool to enhance functionality. The use of frameworks like Angular and RxJS was pivotal in building a robust application. The design methodology revolved around a clear architectural pattern, possibly MVC, with specific attention to UI/UX decisions, ensuring a seamless and intuitive user experience.

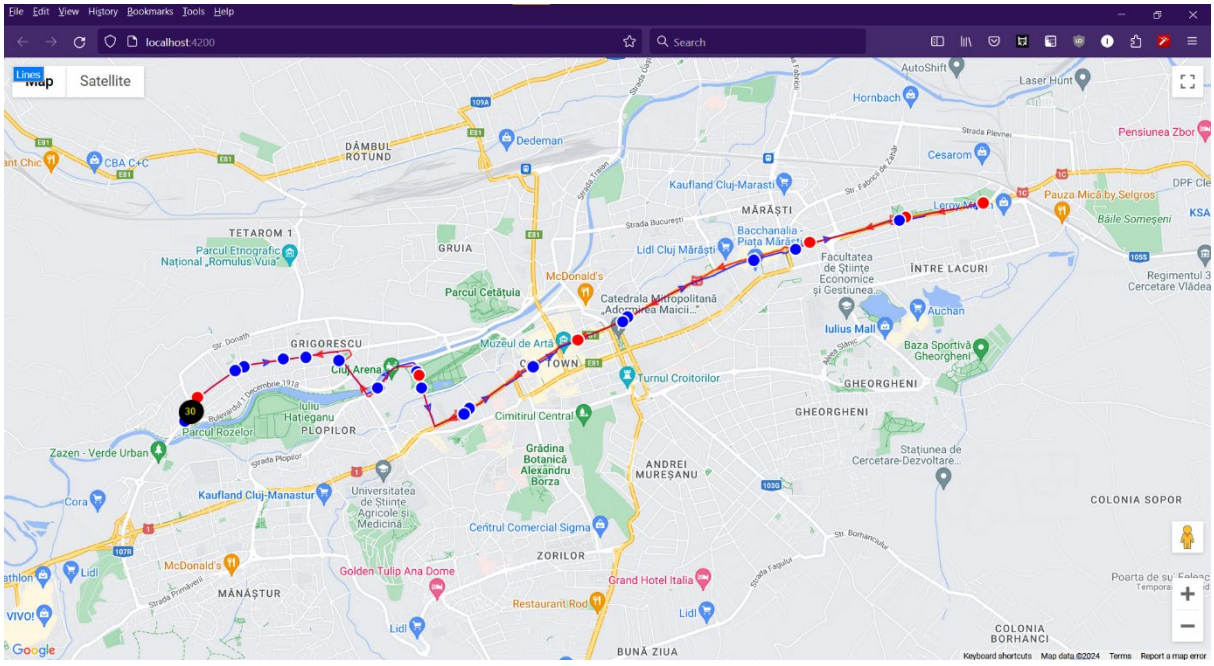

Fig. 3.1.1. User Interface

Reproducibility was a key consideration, with detailed documentation on setting up the development environment and employing version control practices using tools like Git.

3.2 Implementation:

Technical details of the project's implementation shed light on the development environment, including the use of specific IDEs and tools, as well as the application of languages and frameworks such as Angular and TypeScript.

```
    selectRoute(routeId: number) {
    this.clearMapData();
    // Check if the selected route is the same as the
currently active route
    if (routeId === this.selectedRouteId) {
      this.selectedRouteId = null;
      this.selectedTrips = [];
      this.selectedShapes = [];
      this.selectedStops = [];
      this.selectedVehicles = [];
      // Close the routes menu
      this.showRoutesMenu = false;
      return;
    }

    this.selectedRouteId = routeId;

    this.selectedTrips = this.allTrips.filter(
      (trip) => trip.route_id === routeId
    );

    // Extract unique shape IDs from trips
    const shapeIds = [
      ...new Set(this.selectedTrips.map((trip) =>
trip.shape_id)),
    ];

    // Fetch and group shape points for each shape ID
    this.selectedShapes = shapeIds.flatMap((shapeId) =>
      this.allShapes.filter((shape) => shape.shape_id ===
shapeId)
    );

    this.selectedStops = this.allStops;

    // Filter out vehicles with a null trip_id
    this.selectedVehicles = this.allVehicles.filter(
      (vehicle) => vehicle.route_id === routeId &&
vehicle.trip_id != null
    );
```

```
    // Update the map with new data
    this.updateShapesOnMap(this.selectedShapes);
    this.updateVehiclesOnMap(this.selectedVehicles);
    this.updateStopsOnMap(this.selectedStops);

    // Close the routes menu
    this.showRoutesMenu = false;
  }

  private shapePolylines: google.maps.Polyline[] = [];
  private stopMarkers: google.maps.Marker[] = [];
  private vehicleMarkers: google.maps.Marker[] = [];

  clearMapData() {
    // Clear shapes (polylines)
    this.shapePolylines.forEach((polyline) =>
polyline.setMap(null));
    this.shapePolylines = [];

    // Clear stop markers
    this.stopMarkers.forEach((marker) => marker.setMap(null));
    this.stopMarkers = [];

    // Clear vehicle markers
    this.vehicleMarkers.forEach((marker) =>
marker.setMap(null));
    this.vehicleMarkers = [];
  }

  groupShapesByShapeId(shapes: ShapePoint[]): Record<string,
ShapePoint[]> {
    const groupedShapes = shapes.reduce(
      (acc: Record<string, ShapePoint[]>, shape: ShapePoint)
=> {
        if (!acc[shape.shape_id]) {
          acc[shape.shape_id] = [];
        }
        acc[shape.shape_id].push(shape);
        return acc;
      },
      {}
    );

    return groupedShapes;
  }
```

```
  updateShapesOnMap(shapes: ShapePoint[]) {
    const groupedShapes = this.groupShapesByShapeId(shapes);

    Object.keys(groupedShapes).forEach((shapeId) => {
      const shapeArray = groupedShapes[shapeId];
      const isWayDirection = shapeId.endsWith('_0'); //
Assuming _0 is for way

      const polylineColor = isWayDirection ? '#0000FF' :
'#FF0000'; // Blue for way, red for roundway
      const icons = [
        {
          icon: { path:
google.maps.SymbolPath.FORWARD_CLOSED_ARROW },
          offset: '100%',
          repeat: '100px', // Adjust as needed
        },
      ];

      const shapePath = new google.maps.Polyline({
        path: shapeArray.map((pt) => ({
          lat: pt.shape_pt_lat,
          lng: pt.shape_pt_lon,
        })),
        geodesic: true,
        strokeColor: polylineColor,
        strokeOpacity: 0.8,
        strokeWeight: 2,
        icons: icons,
      });

      if (this.mapElement && this.mapElement.googleMap) {
        shapePath.setMap(this.mapElement.googleMap);
      }

      this.shapePolylines.push(shapePath); // Store for later
removal
    });
  }
```

The application's presentation was meticulously designed, with an emphasis on user interface elements and navigation flow. This ensured that users could interact effortlessly with the application, navigating through its various components with ease.

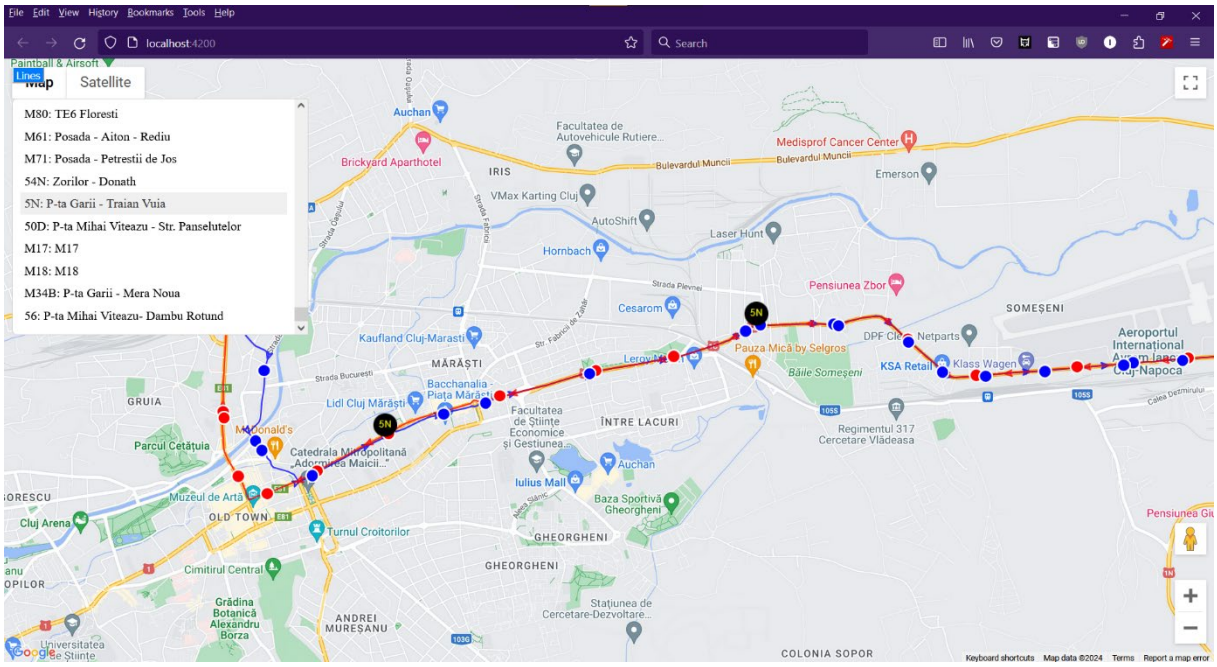

Fig. 3.1.2. Highlited Route with circulating buses

3.3 Testing and Validation:

The testing methodology incorporated a comprehensive strategy, encompassing unit, integration, and acceptance testing methods, utilizing various tools and frameworks. This rigorous testing ensured the application's reliability and effectiveness.

Test results and analysis were thorough, documenting specific bugs encountered and their resolutions, and summarizing the performance testing outcomes. This provided valuable insights into the application's resilience and efficiency under different scenarios.

Experiments and outcome analysis involved user trials to gather direct feedback and observations, complemented by performance testing to assess the system's capabilities under varied conditions. This holistic approach to testing and validation was crucial in fine-tuning the application.

In summary, this section not only demonstrates the practical application of theoretical knowledge but also highlights the author's problem-solving and technical

skills. It offers an in-depth view of the project's development process, illustrating the journey from concept to a fully realized application.

4 Conclusions

4.1 Achieved Results

In this section, the significant outcomes of the project are critically evaluated, showcasing its contributions to real-time public transport tracking and urban mobility solutions. The project's implementation success is a testament to the effective integration of real-time tracking, user interface design, and data handling. Performance metrics reveal the system's efficiency, accuracy, and responsiveness, underlining its reliability in an urban setting. User feedback, an invaluable aspect of the project, has highlighted high satisfaction levels and provided insights into user preferences and areas of improvement. These metrics and testimonials can be visually represented through charts and graphs, adding a quantitative dimension to the project's success.

A comparative analysis with existing systems reveals the project's competitive edge. This includes benchmarking features and performance against established solutions, while also highlighting unique selling points and innovative approaches that set the project apart. Comparative tables or diagrams can effectively illustrate these distinctions.

The list of contributions includes technical innovations such as breakthroughs in GPS data processing and UI/UX enhancements that have significantly improved user experience. The project has also offered new perspectives and solutions in the domain of urban mobility, contributing to broader discussions and advancements in the field. Summaries or visual representations of these key contributions can effectively convey the project's impact.

4.2 Future Development Directions

Looking forward, the project holds substantial potential for expansion and enhancement. Technical enhancements could include the integration of more comprehensive APIs, refining algorithms for better performance, and adopting new technologies that emerge in the field. Conceptual diagrams or technology roadmaps could effectively outline these potential upgrades.

Feature expansion is another exciting avenue, with possibilities for adding new functionalities based on evolving user demands and technological advancements. Enhanced user interaction models could make the application even more engaging. Mock-ups or concept art for these proposed features would provide a glimpse into what these enhancements might look like.

Scalability and adaptability are crucial for the project's growth. Expansion plans might involve scaling the application to other cities or regions, necessitating customization for different urban settings or languages. Maps showing potential expansion areas or flowcharts for the adaptation process could visually represent these plans.

Lastly, the project's long-term vision includes contributing to sustainable urban mobility. Collaborative opportunities with government bodies or transport authorities could be explored to maximize the project's reach and impact. Infographics illustrating potential environmental impacts or partnership models would provide a clear view of these aspirations.

5 Bibliography

[1] Centrul de Transport Public Cluj-Napoca. (n.d.). TranZy: The Application Enhancing Urban Mobility. Retrieved January 16, 2024, from https://ctpcj.ro/index.php/ro/despre-noi/stiri/tranzy-aplicatia-care-eficientizeaza-mobilitatea-urbana/1378

[2] Centrul de Transport Public Cluj-Napoca. (n.d.). Cluj-Napoca Public Transport Center. Retrieved January 16, 2024, from https://ctpcj.ro/index.php/ro/

[3] FlashWebIT. (n.d.). cfr-iris-scraper: CFR Iris Scraper GitHub Repository. Retrieved January 16, 2024, from https://github.com/FlashWebIT/cfr-iris-scraper/tree/master

[4] Angular. (n.d.). Official Angular Documentation. Retrieved January 16, 2024, from https://angular.io/