POLITECNICO DI TORINO

INTERDISCIPLINARY PROJECT

REPORT - GROUP I

Ride your bike

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1 Introduction

This report presents the design, engineering, and demonstration of a comprehensive system aimed at incentivizing mobility through bike usage [1]. The primary objective of this project is to develop a system that rewards individuals who regularly engage in biking activities based on the distance covered and the frequency of their trips [2] and also tracking a user regarding path taken and the statistics related for each of them. By leveraging a user-friendly mobile application, individuals will have the ability to initiate and conclude their rides [3], while the app diligently monitors each journey, collecting essential statistics. Additionally, the system will incorporate measures to detect potential fraudulent practices where users may attempt to deceive the system by utilizing alternative means of transportation while posing as active bike riders [15]. To encourage continued bike usage, the system will implement various reward mechanisms, drawing inspiration from gamification strategies such as scoring systems, sweepstakes, and other engaging solutions [4].

The anticipated outcome of this project is the delivery of a prototype that encompasses a comprehensive backend infrastructure responsible for data collection and management, alongside a feature-rich mobile application targeting end-users [19]. This mobile app will not only facilitate the tracking and verification of rides [8] but will also collect invaluable data for further analysis [16]. Users will benefit from personalized analytics, enabling them to review their ride history, assess their performance on individual trips, and gain insights into their biking habits [5]. Furthermore, the system will be equipped to manage incentives and prizes, leveraging the potential of gamification to foster greater user engagement [17]. Potential approaches include sweepstakes based on usage points, user rankings, and friendly competition among participants.

To successfully execute this project, a range of skills will be utilized. Proficiency in Python programming is essential for effective data collection and management, while expertise in database design using SQL and administration is important for developing a robust backend solution using C# for data processing [7]. Moreover, application programming using React Native and GPS system interfacing are vital for seamless integration between the mobile app and the biking system, ensuring accurate tracking and verification of rides. Lastly, the creation of an intuitive and informative dashboard will enhance user experience and aid in visualizing key metrics.

Through the realization of this system, we aim to promote a culture of active mobility, encouraging individuals to adopt biking as a preferred mode of transportation [18]. By providing tangible rewards and utilizing gamification elements, we aspire to make the experience engaging and gratifying, ultimately fostering a sustainable and healthier lifestyle [9]. This report will outline the various components, methodologies, and outcomes of the project, highlighting the advancements made in the field of incentivized bike mobility.

1.1 State of the art review

The use of GPS (Global Positioning System) technology has entirely altered how we track and monitor user activities. Numerous apps that follow user trajectories and offer insightful data on their physical activities have been developed as a result of the accessibility of GPS-enabled devices, such as smartphones and wearable technology [11]. GPS-based user activity tracking applications collect location information using GPS technology [6], which is then processed to produce detailed activity profiles. Real-time monitoring, distance calculation, speed measurement, route mapping, and elevation tracking are common features. speed measurement is done through gyroscope of the mobile. Numerous features are available in modern mobile apps to improve user experiences. These consist of intuitive user interfaces, dynamic navigation, real-time updates, personalized recommendations, social media integration, and cross-platform interoperability [12]. With the continued growth of technology and rising consumer demands, the future of developing mobile apps appears bright [10]. It's anticipated that progressive web apps will acquire greater acceptance and obfuscate the distinction between web pages and native apps. Predictive analytics and personalized experiences will be driven by the convergence of AI and ML [13]. Additionally, when 5G networks are more widely used, greater data transfer speeds will be possible, creating new opportunities for high-quality entertainment and real-time interactions [14].

1.2 Requirements Review

In the table below, the goal of the project and the requirements have been shown:

Goals of the project
• Motivating people to bike through prizes • Track users' ride and provide statistics • Finding biking community by joining events
User requirements
• User-friendly mobile application • Interact with the community (rankings and events) • Gamification leading to prizes
Functional requirements
• Account management • Provide a ranking list • Show real-time statistics • Tracking the user's path • Store the travel history • Avoid cheating by the user • Calculate the total distance taken by the user for each trip
Technical requirements
• Image Processing and anti-cheating: Python • Data Processing: C# • Application: React Native • Database: PostgreSQL

Table 1: Requirements Review.

2 System Design

2.1 General System Architecture

Figure 1 is an overview of our high-level system design.

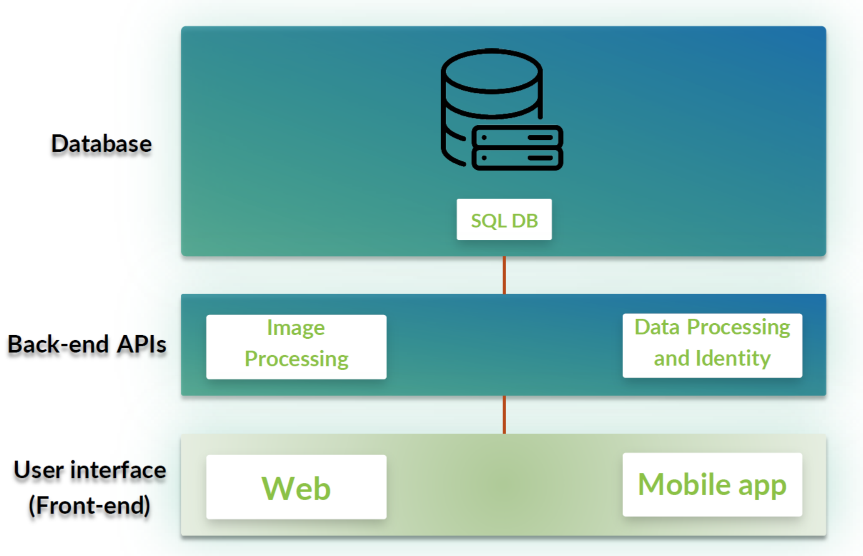


Figure 1: High-level system design

The system architecture is divided into two primary components: the frontend and the backend. The frontend of the system is designed as a mobile application, providing an intuitive and user-friendly interface for end users. Developed using React Native, a popular cross-platform framework, the mobile app offers a consistent experience across different devices and operating systems. Users can access the app on their smartphones and interact with its features and functionalities to start and end bike rides, monitor their statistics, and view personalized analytics.

On the other hand, the backend of the system consists of a web application and a database. The web application, built using React Js, serves as the control center for system administrators. It provides an interface through which administrators can manage various aspects of the system, such as user accounts, rewards, and system settings. The web application acts as a hub for processing and analyzing the collected data, ensuring its accuracy and integrity.

The database used in the system is PostgreSQL, a robust and scalable relational database management system. It serves as the central repository for storing all the relevant data, including user profiles, ride history, rewards, and other system information. The database plays a crucial role in managing and organizing the vast amount of data generated by the system, enabling efficient data retrieval and processing.

The interaction between the frontend and the backend is essential for the system's functionality. The mobile app communicates with the web application and database through secure APIs (Application Programming Interfaces). This interaction allows for real-time data synchronization, ensuring that the user's ride information, statistics, and analytics are accurately captured and displayed. Additionally, the backend algorithms play a vital role in verifying the authenticity of bike rides and detecting any attempts at cheating or fraudulent behavior.

The anti-cheating section is divided into two main sections. First, in order to test the algorithm, a sample dataset has to be to be used and from that, GPS data are utilized. The Strava dataset, which gives us information on users' travels and activities, is where we start by obtaining data. After retrieving the data, we move on to cleaning and converting it. It guarantees that it is without any mistakes and in the proper format for our algorithm. Then we put our algorithms to the test to make sure our GPS tracking system is highly accurate and dependable. We utilize the mobile device's GPS to determine the privilege of latitude and longitude. Image recognition is the second module. On our dataset, we have implemented a Tensorflow approach to identify bicycles. It is examined to guarantee its accuracy in actual circumstances. To improve the usability and functionality of our system, we apply this method for object detection. A REST API is used to access these two components. Our data processing component, benefits from this API's smooth user interface. Once processed, this data is fed into both mobile application and web admin platform.

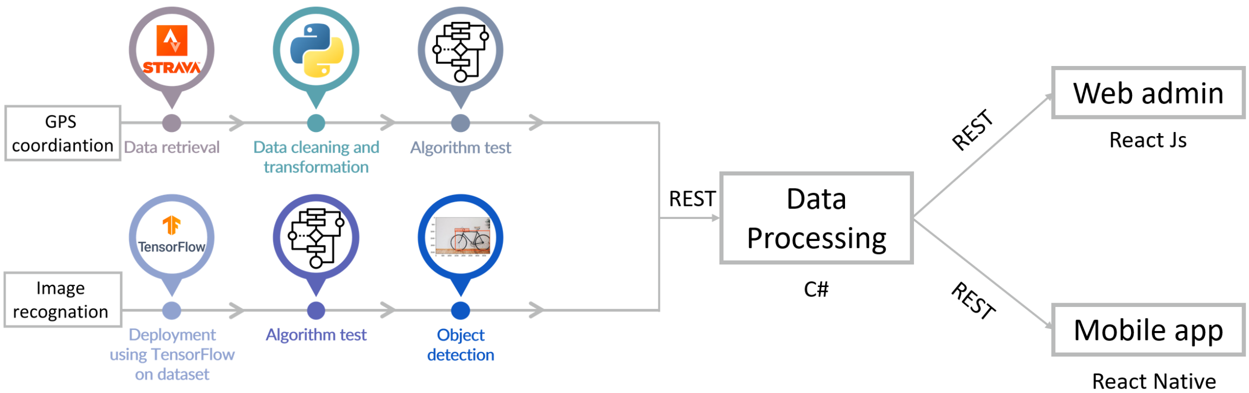


Figure 2: High-level stack system design

2.2 Application design

The mobile application design of the incentivized mobility system offers a range of features and functionalities to enhance user experience and discourage cheating. Users can sign in to their accounts and access various sections within the app to view statistics from previous trips, initiate new rides, explore events, and register for them.

To ensure the authenticity of bike rides, the app incorporates an anti-cheating algorithm that utilizes image processing. Before starting a trip, the user is prompted to capture a picture of the bike using the device's camera. This image is processed to verify if the device being used is indeed a bike, adding an extra layer of security against fraudulent behavior.

During a trip, the application captures the user's speed and location every 4 seconds, providing real-time data for analysis. To prevent cheating, the app periodically checks if the user's speed exceeds 25 km/h. If cheating is detected, a notification is displayed as a warning. If the speed violation occurs again, the trip is automatically terminated by the system. Additionally, if the user remains stationary for 10 minutes, a pop-up notification appears, giving the option to continue or end the trip. If no response is received for the second pop-up, the app automatically ends the trip.

At the end of each trip, users can review trip details, including a map displaying the route taken, average speed, duration, and total distance covered. This comprehensive overview allows users to assess their performance and track their progress over time.

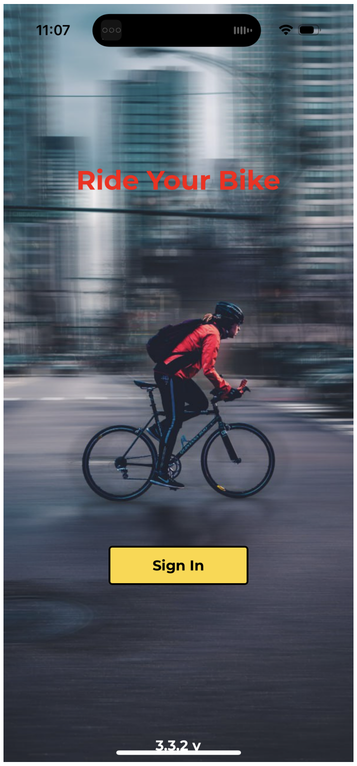
The application also fosters community engagement by providing event subscriptions, enabling users to connect with other bikers and create a sense of camaraderie. Each event is associated with predefined awards that are determined by the system administrators through the web admin interface. These awards are categorized based on rankings assigned to specific distances covered by the user. By participating in events and achieving milestones, users can earn recognition and rewards, fostering motivation and a sense of accomplishment within the community.

Overall, the application design incorporates advanced features such as image processing for bike verification, real-time tracking of speed and location, and interactive notifications to discourage cheating and ensure data accuracy. The inclusion of community-building elements and predefined awards further enhances user engagement and encourages participation in events, promoting a vibrant and supportive biking community.

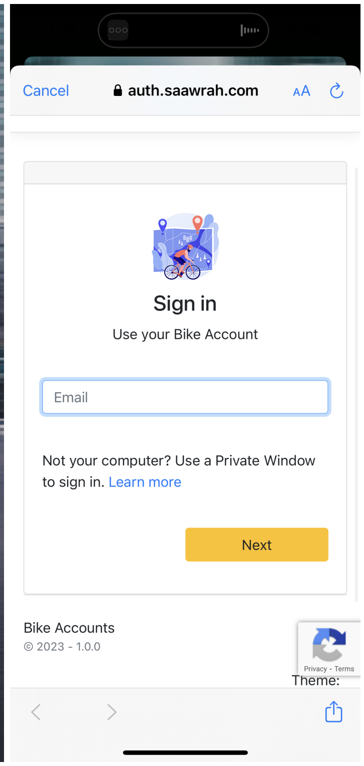
2.3 Web page design

The web page consists of four main sections:

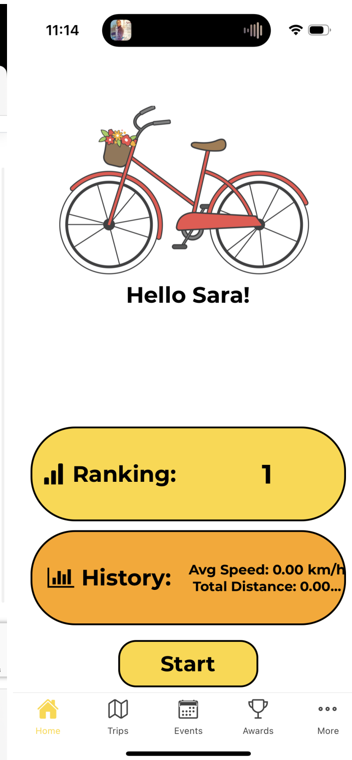
- Login and Registration
- Event page
- Award page
- Trips page



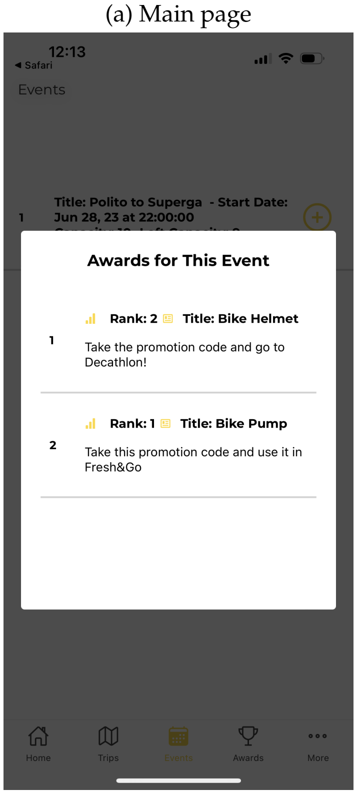
(a) Main page



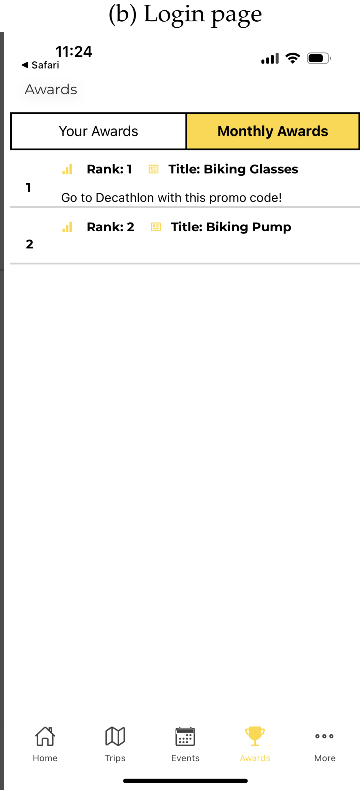
(b) Login page



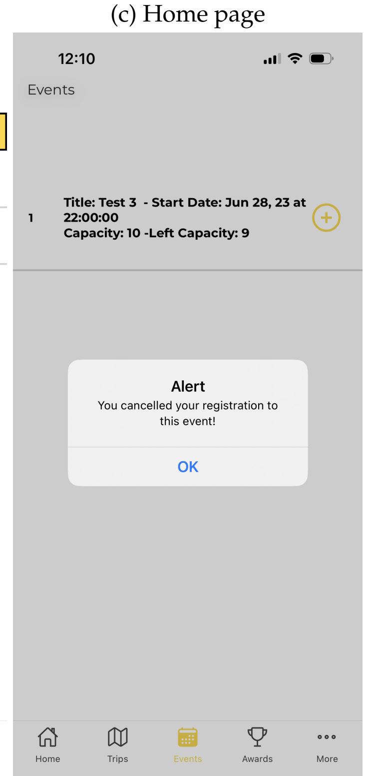
(c) Home page



(d) Events page



(e) Awards page



(f) Event registration

Figure 3: Mobile application pages.

Login interface is exclusively accessible to admin users. When the server is running, admins can log into the web system using their own accounts.

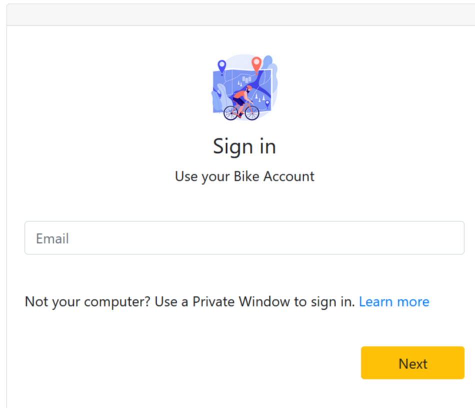


Figure 4: Login page

In the Event page, Admins can utilize this interface to publish and view cycling event information.

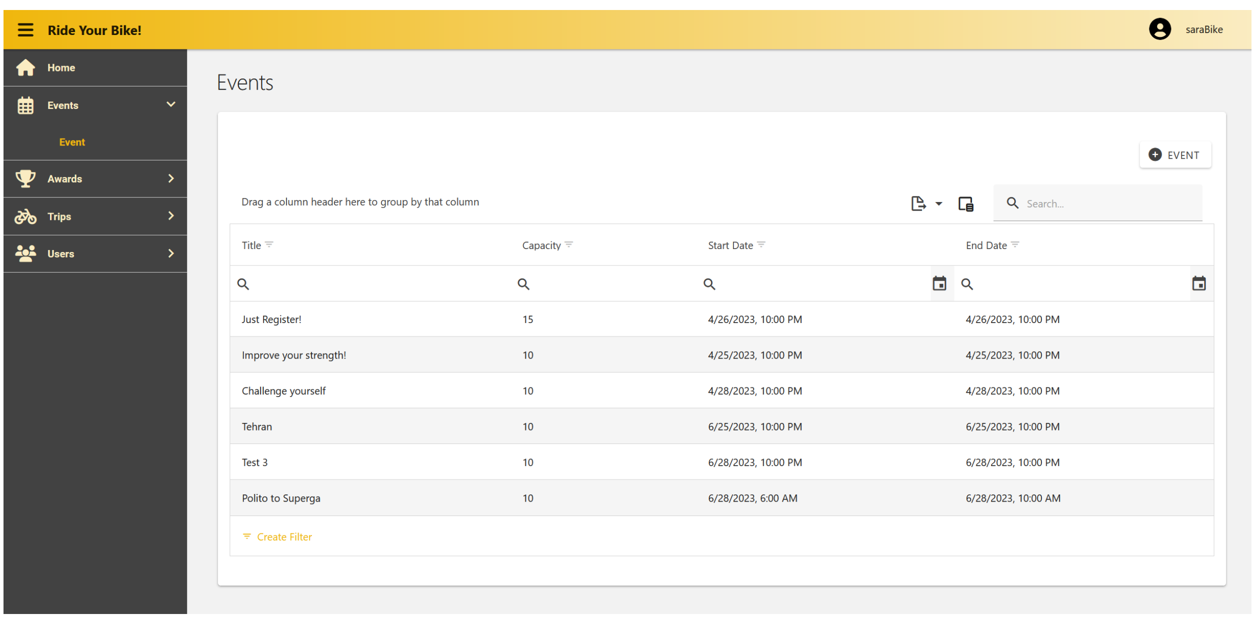


Figure 5: Event page

In the Award page, Admins can utilize this interface to publish and view awards information.

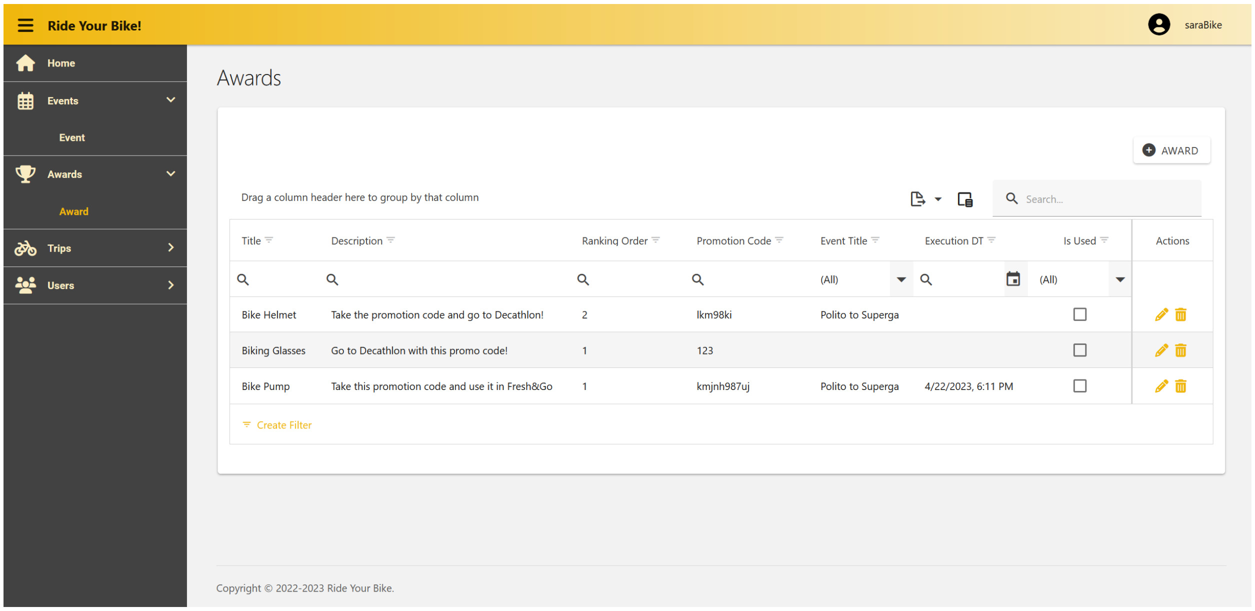


Figure 6: Award page

In the Trips page, Admins have the capability to access and review information regarding all trips through this interface.

3 Algorithm Design

3.1 Tracking and anti-cheating algorithm

OpenStreetMap GPS traces, Kaggle Datasets, and GPS data vendors are a few of the places where we can discover datasets containing GPS coordinates from various locations for the purpose of testing the algorithm. However, Strava Global Heatmap is among the best datasets. The Strava API provides multiple endpoints for retrieving cycling-related data, among other activity classifications. This heatmap can be used to extract information on bicycle activity. Each route's output format is based on the GPX standard.

A popular XML-based file format for sharing GPS data between programs and devices is called GPX (GPS Exchange Format). A GPX file contains data such as latitude, longitude, elevation, and timestamps that can be used to indicate a user's travel, the position of certain sites of interest, or to specify a route [22] for subsequent navigation. There are benefits of converting GPX files to JSON format, including data structure, simplicity, readability, and compatibility. JSON is a popular data format that is used for data interchange between various systems and web APIs.

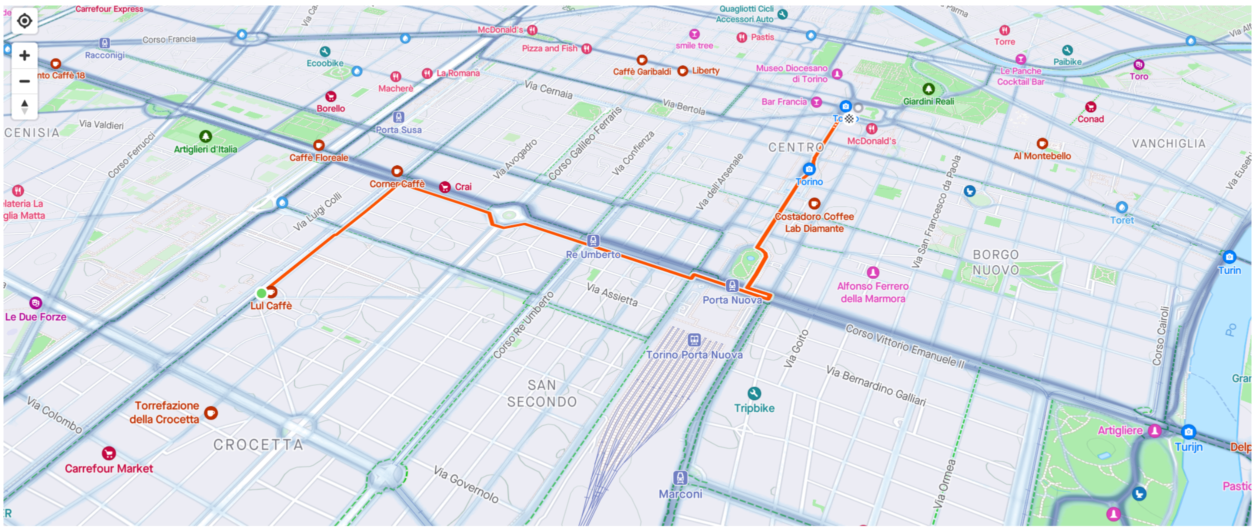


Figure 7: Route from Polito to Piazza castello.

As can be seen, this is an illustration of the route from polito to piazza castello. On the right, the converted json output of the path is displayed in Figure 7. The problem with all datasets is that their gps coordinates are less accurate than those of Strava. The issue shared by all datasets, however, is that none of them contain the timestamp associated with the route taken by the rider, as there is no speed data corresponding to the path taken to calculate the time. However, with the aid of the estimated average time to traverse a path, the time for each coordination can be modified.

Our solution is designed to meet four fundamental functional requirements. First, it could record the user's movements in real-time using advanced GPS technology to precisely trace the user's path. This brings us to the second feature, which is storing each user's travel history. This not only provides essential information for the user's reference but also enables us to analyze trends and patterns over time. Now, protecting the system's integrity is crucial. So, we've implemented a feature to prevent trickery. Using complex algorithms, we are able to detect anomalies in speed and location data, thereby effectively preventing system abuse. In addition, the system computes the total distance traveled during each journey.

The testing of our algorithm is an integral part of our procedure, and we concentrate on three main areas. The first is the precision of the coordinates; our GPS tracking is accurate and reliable. The second factor is total distance precision. Our algorithm calculates the traveled distance with a high degree of accuracy, ensuring that users have access to the most precise information regarding their travels. Finally, we must conduct real-world testing to ensure that our system is robust and capable of handling a variety of scenarios. We assess for "fake threats" by using our app on buses, cars, and scooters, among other modes of transportation. This helps us refine our algorithm for detecting deception and ensures that our system produces accurate results.

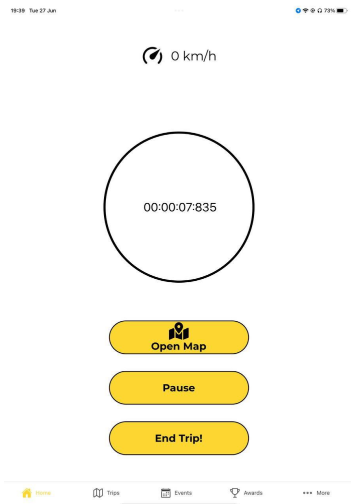
latitude	longitude	elevation	ll_dist	ll_dist_traveled	speed	timestamp	dspan	tspan	cspeed	diff	cheating
45.06247	7.663	252.97	0	0	0	2023-05-15 18:48:17					
45.06322	7.663543319	253.02	0.093709	0.093709	7.6768	2023-05-15 18:48:24	0.094	7	6.5768	-1.1	FALSE
45.06397	7.664086652	253.01	0.093709	0.187418	4.083657143	2023-05-15 18:48:31	0.187	14	-0.126342857	-4.21	FALSE
45.06472	7.66463	252.85	0.093709	0.281127	3.5776	2023-05-15 18:48:38	0.281	21	0.2276	-3.35	FALSE
45.06474	7.66465	252.85	0.002724	0.283851	7.522742857	2023-05-15 18:48:45	0.284	28	4.272742857	-3.25	FALSE
45.06473	7.66469	252.79	0.003334	0.287185	7.345828571	2023-05-15 18:48:52	0.287	35	5.325828571	-2.02	FALSE
45.06525	7.665074997	252.79	0.065271	0.352456	19.83817143	2023-05-15 18:48:59	0.352	42	19.46817143	-0.37	FALSE
45.06577	7.66546	252.54	0.065271	0.417727	19.83817143	2023-05-15 18:49:06	0.418	49	18.98817143	-0.85	FALSE
45.066415	7.665909995	252.37	0.07998	0.497707	26.56228571	2023-05-15 18:49:13	0.498	56	31.12228571	4.56	FALSE
45.06706	7.66636	252.3	0.07998	0.577687	26.56228571	2023-05-15 18:49:20	0.578	63	30.11228571	3.55	FALSE
45.06672001	7.667303345	251.62	0.0832	0.660887	28.03428571	2023-05-15 18:49:27	0.661	70	32.07428571	4.04	FALSE
45.06638001	7.668246678	251.15	0.0832	0.744087	28.03428571	2023-05-15 18:49:34	0.744	77	31.27428571	3.24	FALSE
45.06604	7.66919	250.48	0.0832	0.827287	24.03428571	2023-05-15 18:49:41	0.827	84	26.60428571	2.57	FALSE
45.06568	7.67014	250.17	0.084696	0.911983	23.71817143	2023-05-15 18:49:48	0.912	91	26.35817143	2.64	FALSE
45.06517	7.67035	249.96	0.059078	0.971061	21.00708571	2023-05-15 18:49:55	0.971	98	16.34708571	-4.66	FALSE
45.06503	7.67079	249.86	0.037913	1.008974	17.33165714	2023-05-15 18:50:02	1.009	105	16.07165714	-1.26	FALSE
45.0652	7.67154	249.34	0.061881	1.070855	19.28845714	2023-05-15 18:50:09	1.071	112	16.15845714	-3.13	FALSE
45.06483502	7.672545032	248.41	0.088783	1.159638	6.905142857	2023-05-15 18:50:16	1.16	119	10.41514286	3.51	FALSE
45.06447004	7.673550051	248.02	0.088783	1.248421	15.48662857	2023-05-15 18:50:23	1.248	126	20.40662857	4.92	FALSE
45.06410504	7.674555058	247.37	0.088783	1.337204	19.99588571	2023-05-15 18:50:30	1.337	133	24.39588571	4.4	FALSE
45.06374004	7.675560051	246.94	0.088783	1.425987	14.27565714	2023-05-15 18:50:37	1.426	140	18.19565714	3.92	FALSE
45.06337502	7.676565032	246.33	0.088783	1.51477	11.32982857	2023-05-15 18:50:44	1.515	147	14.81982857	3.49	FALSE
45.06301	7.67757	246.05	0.088783	1.603553	8.754285714	2023-05-15 18:50:51	1.604	154	11.85428571	3.1	FALSE
45.06316	7.67769	246.14	0.019164	1.622717	8.760685714	2023-05-15 18:50:58	1.623	161	4.240685714	-4.52	FALSE
45.06286001	7.678493342	245.94	0.071392	1.694109	6.905142857	2023-05-15 18:51:05	1.694	168	3.245142857	-3.66	FALSE
45.06256001	7.679296675	246.07	0.071392	1.765501	7.6768	2023-05-15 18:51:12	1.766	175	3.9968	-3.68	FALSE
45.06226	7.6801	245.8	0.071392	1.836893	4.083657143	2023-05-15 18:51:19	1.837	182	0.393657143	-3.69	FALSE
45.06241	7.6802	245.99	0.018442	1.855335	3.5776	2023-05-15 18:51:26	1.855	189	0.6676	-2.91	FALSE
45.06267	7.67946	245.99	0.064934	1.920269	1.2448	2023-05-15 18:51:33	1.92	196	-3.3452	-4.59	FALSE
45.06317	7.67984	246.2	0.063121	1.98339	2.3446	2023-05-15 18:51:40	1.983	203	0.0346	-2.31	FALSE
45.0637	7.68021	246.23	0.065729	2.049119	0	2023-05-15 18:51:47	2.049	210	-3.08	-3.08	FALSE

Figure 8: Output of the algorithm.

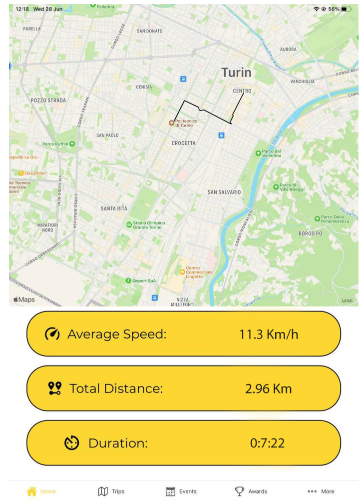
The output of the initial algorithm test for the example path from Polito to Piazza Castello is depicted in Figure 8. A straightforward anti-cheating system for detecting potential cheating can consist of detecting speed spikes or unrealistic speeds. We can compute the speed differences between consecutive data points and then set a maximum allowable speed difference threshold. If the difference exceeds this threshold, the data point can be flagged as potentially fraudulent.

In the provided code, a "calculated speed" is present. It is a variable used to retain the user's (the cyclist's) calculated speed based on the GPS coordinates (latitude and longitude) and timestamps provided. The code calculates the "calculated speed" for each consecutive pair of GPS coordinates in the data frame. This enables us to analyze the calculated speed across the entire dataset, and in this particular use case, to detect possible deception by comparing the "calculated speed" to a predetermined speed threshold. Another function is distance calculation. Using the Haversine formula [20], this function calculates the ground distance between two latitude and longitude coordinates on Earth. Given their latitudes and longitudes, the Haversine formula is used to calculate the great-circle distance between two points on a sphere. The function returns the calculated distance in kilometers between two coordinates of latitude and longitude.

After validating the algorithm on the dataset, we transitioned to utilizing the GPS functionality of the mobile device, which provides precise latitude and longitude coordinates. By leveraging this GPS data, we were able to accurately track and record the route taken from Polito to Piazza Castello. The figures below depict the visual representation of this route, along with corresponding statistics for the trip.



(a) Home page while on a trip



(b) Mapped route and its statistics

Figure 9: Route from Polito to Piazza Castello on mobile app.

By utilizing the mobile device's GPS capabilities, we obtained real-time location data, enabling us to precisely track the user's journey and derive insightful statistics about the trip. These figures demonstrate the effectiveness and accuracy of our system in capturing and analyzing biking activities, providing valuable information to users regarding their routes, performance, and overall biking experience.

3.2 Image recognition

To mitigate instances of cheating and ensure fair participation in prize competitions, we have implemented a dedicated micro-service specifically designed to detect any fraudulent attempts made by users. This micro-service has been developed using the Python programming language, utilizing the Flask framework for efficient and streamlined development.

The core mechanism employed to prevent cheating involves leveraging image processing techniques [21]. At the conclusion of each user's trip, they are prompted to capture an image of their bicycle, which is then transmitted to our anti-cheating server.

This server serves as the input for an object detection model, specifically the pre-trained MASK-RCNN.

The MASK-RCNN model used in our system has been trained on the COCO dataset, a comprehensive and extensively curated dataset specifically designed for object detection and image segmentation tasks. This dataset includes a diverse range of labeled objects, encompassing bicycles as one of the defined categories.

To optimize the performance of our model and ensure accurate detection, we provide users with a defined window or frame within which they must capture the bicycle image. This window is carefully designed to restrict the captured image to solely the bicycle itself, excluding any background objects that might introduce bias or impact the model's performance.

By employing this robust framework, incorporating image processing techniques, and utilizing a pre-trained object detection model trained on a rich dataset, we aim to effectively detect and prevent cheating attempts, ensuring a fair and equitable environment for all participants.

Figure 10: Bike detection

4 Conclusion

In conclusion, this report has presented the design, engineering, and demonstration of a comprehensive system that incentivizes mobility through bike usage. Through the development of a user-friendly mobile application, we have successfully created a platform that rewards individuals for engaging in regular biking activities based on distance and frequency. The system incorporates advanced features such as real-time tracking, personalized analytics, and anti-cheating algorithms to ensure accuracy and fairness.

By leveraging the GPS capabilities of mobile devices, we have enabled precise tracking of user routes, providing valuable statistics and insights into their biking habits. The implementation of gamification elements, such as scoring systems and event participation, fosters user engagement and motivation. Additionally, our anti-cheating mechanisms, including image processing and object detection, ensure the integrity of the system and prevent fraudulent practices.

Throughout the project, we have utilized a range of skills, including Python programming, database management, application development, and GPS system integration. These skills have allowed us to create a robust backend infrastructure, efficient data collection and management processes, and an intuitive user interface.

The anticipated outcome of the project is the delivery of a prototype system that showcases the full functionality of incentivized bike mobility. The system has the potential to promote sustainable transportation choices, improve individual fitness and well-being, and foster a sense of community among bikers.

In summary, this project has successfully demonstrated the effectiveness and potential of incentivized mobility through bike usage. The system has addressed key challenges such as cheating prevention, accurate tracking, and user engagement, offering a comprehensive solution that encourages individuals to adopt biking as a preferred mode of transportation.

5 Reference

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