

TickTrax: A Mobile and Web-Based Application for Tick Monitoring and Analysis

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Abstract—Due to the impact of climate change on environmental factors, tick populations are expanding in various regions, posing a growing public health concern due to the tick-borne pathogens (TBP) they transmit. To address this issue and gather valuable insights for preventing tick-borne diseases (TBD), the TickTrax software initiative introduces a website and mobile application that utilizes citizen science to monitor and track tick distribution. By adopting a citizen science-based approach, TickTrax significantly enhances the size and diversity of data collection. The TickTrax software platform offers an intuitive interface, enabling users to contribute valuable tick-related data through both the website and mobile application. The data is aggregated into a live database, which visualizes tick locations across different regions. The project's key components encompass user input, data visualizations, and the ability to export reports for further analysis. Through these features, TickTrax aims to empower the public to actively participate in tick monitoring efforts.

Index Terms—Tick-borne Diseases, Tick-borne pathogens, Citizen Science, Data Management, Data Analysis, Data Visualization, User Interface, Web Framework, Mobile Application, Software Engineering

I. INTRODUCTION

Ticks have the potential to transmit bacterial, protozoan, and viral pathogens and can carry more than one agent simultaneously [1]. As climate change continues to influence environmental factors, tick populations are expanding in geographic areas throughout the US, leading to an emerging public health concern regarding tick-borne diseases (TBD) [2]. The increase in the prevalence and transmission of tick-borne diseases are becoming an alarming public health issue in the US. Unfortunately, the limitations of tick surveillance and tracking leave the western US at higher risks of tick-borne disease outbreaks, especially amongst rural populations [3]. Effectively preventing and diagnosing tick-borne diseases depends on accurately identifying instances of tick bites and the specific pathogens transmitted by ticks. Information on tick locations and prevalent tick-borne diseases found in the US plays a crucial role in determining diagnosis and treatment for the public.

One of the main challenges confronting this study is the scarcity of data required to accurately observe the various species of ticks in different regions [4]. Regrettably, the current nationwide mappings of tick locations are incomplete due to the missing geographical data aggravated by climate change's ongoing influence on tick populations [5].

According to surveillance data, tick-borne diseases provide critically important information to identify where cases have occurred. However, the reported cases can be inaccurate when exposure occurs outside the county or state of residence [6]. To establish a valuable tick database, information needs to be gathered from the affected regions. Unfortunately, this process can be time-consuming and expensive.

To overcome this hurdle, this paper introduces TickTrax, an accessible website, and mobile application-based platform that collects data but also generates a diverse data set for ticks. TickTrax aims at improving the consistency of data collection, prediction of tick presence and prevalence, and leading to faster responses to tick-borne diseases. TickTrax was implemented to support the Research Infrastructure Improvement (RII) Track-2 FEC Leveraging Big Data to Improve Prediction of Tick-Borne Disease Patterns and Dynamics. Ultimately, the TickTrax platform will assist in determining the significance of ticks in their respective environments.

The subsequent part of the paper is structured as follows: Section II provides background information and a brief literature review, Section III delves into the detailed specifications of the software employed, Section IV elucidates the overarching principles and considerations of the software design, and Section V concludes the paper by summarizing the main outcome and proposes avenues for future work.

II. BACKGROUND AND RELATED WORKS

Citizen-based science programs face several limitations including uneven program awareness, which can result in both a lack of diversity in the participation pool and potential sampling bias. However, the data collected by citizen science proves beneficial by providing insight into geographical patterns of exposure to ticks and tick-borne pathogens (TBP)

that are not limited by jurisdictional boundaries [7]. Public health initiatives and strategies also help mitigate the impact and detection of current and emerging tick-borne diseases by increasing public awareness [8]. In recent years, there has been a significant increase in research and data collection efforts focused on exploring various methods and techniques for gathering tick data.

Significant work has already been underway by many organizations to create a tick-based database to track ticks and tick-borne diseases. The current work by the Center for Disease Control and Prevention (CDC) and the prevention-funded Regional Centers for Excellence in Vector-Borne Diseases in five US university institutions is at the forefront of citizen-based data collection. The main goals of this initiative are to conduct research to prevent tick and mosquito bites and/or suppress populations of regionally important ticks and mosquitoes and their associated human disease pathogens [9].

Outside of the CDC's efforts, several other attempts have been made to address the scarcity of tick data such as TickNET. TickNET is a public network that employs data from state health departments and academic institutions to assist in the surveillance of tick-borne diseases. Ultimately the goal of TickNET is to create a collaborative network of educators and health officials from the federal and state level to aid in the surveillance, prevention, and identification of emerging tick-borne diseases [10].

In addition to data collection, a citizen scientist approach was used by Northern Arizona University to collect data across the US surveying tick and tick-borne pathogens via the Bay Area Lyme Foundation website. A total of 12,130 submissions from across the U.S. and Puerto Rico resulted in a sum of 16,080 ticks collected and tested for pathogens [7].

TickTrax introduces a software and citizen science approach regarding tick locations in the U.S. by mapping associated locations, developing a more robust data collection method, and increasing access to healthcare information via a user-friendly website and mobile application. The primary drive and motivation to produce the TickTrax software is to support under-served rural populations who are at high risk of emerging tick populations and their associated tick-borne diseases. Ultimately, TickTrax aims to link findings to environmental, and socioeconomic factors on an academic, state, and local level to create a connected network.

III. SOFTWARE SPECIFICATIONS

Software specifications were developed with stakeholders including academic researchers, a software engineer experienced in full-stack web development, and a citizen who has experience with tick interactions that helped outline the critical functionality and attain detailed requirements of the software system. Additionally, interviews were conducted to determine the goals, objectives, and scope of the software. The insights provided outlined the expectations of the software and how it would meet the needs and the roles of citizens, researchers, and administrators.

The requirements for the software were determined through *functional requirements*, which determine the specific features and intended purpose of the software, and *non-functional requirements*, which determine the performance and constraints of the system, using the agile development method and separated into critical functions as described in Table I and Table II, respectively.

TABLE I: Functional Requirements

Functional Requirements	Description
Account Management	TickTrax shall provide user account management functionality to allow users to create an account, log into an existing account, and log out of the account.
Landing Page	TickTrax shall display a landing page with general information to educate the public about tick-related educational information.
User Validation	TickTrax shall validate the information entered by the user via the forms on the website.
Photo Submission & Display	TickTrax shall allow users to submit photos, submit different photos varying by angles, and display the photos submitted by the user.
Tick Information & Management	TickTrax shall display information about the submitted tick to the user, revise the information submitted, and display a list of ticks for the user.
Location Based Tick Display	TickTrax shall allow the user to input location data and display the different ticks in the user's area.
Data Management & Analysis	TickTrax shall allow administrative users to view a holistic view of the data, download the demographics database, and sort the data by different filters.
User Feedback & Support	TickTrax shall allow the users to communicate about problems in the mobile and website applications.

TABLE II: Non-Functional Requirements

Non-Functional Requirements	Description
Compatibility	TickTrax shall be compatible with iOS and Android mobile phones.
Browser Compatibility	TickTrax shall run on Chromium and Firefox-based browsers.
Technology Stack	TickTrax shall utilize Quasar platform based on Vue.js.
Security	TickTrax shall utilize encrypted communications for all sessions.
Database	TickTrax shall utilize a robust database to store the tick data.
Performance	TickTrax shall optimize performance for CPU performance.
Accessibility	TickTrax shall implement accessible website standards.

In addition, use cases were then captured to describe the functional requirements of the software system for TickTrax from the perspective of different users. The use case diagram, Figure 1, represents the interaction between the actor and the system which is mapped with the actions to achieve a functional and user-friendly website. TickTrax users consist of the general user intended for regular citizens, the elevated user for a researcher, and the superuser as a system administrator, who can update the role of either the general user or the elevated user.

The description of each use case is as follows:

- **UC01 Sign Up**
 - Users can create standard accounts through the website or mobile application, with securely hashed credentials stored in the database.
- **UC02 Login**
 - Authenticated users can login using their credentials on the website or mobile application, with session ID returned upon successful login.

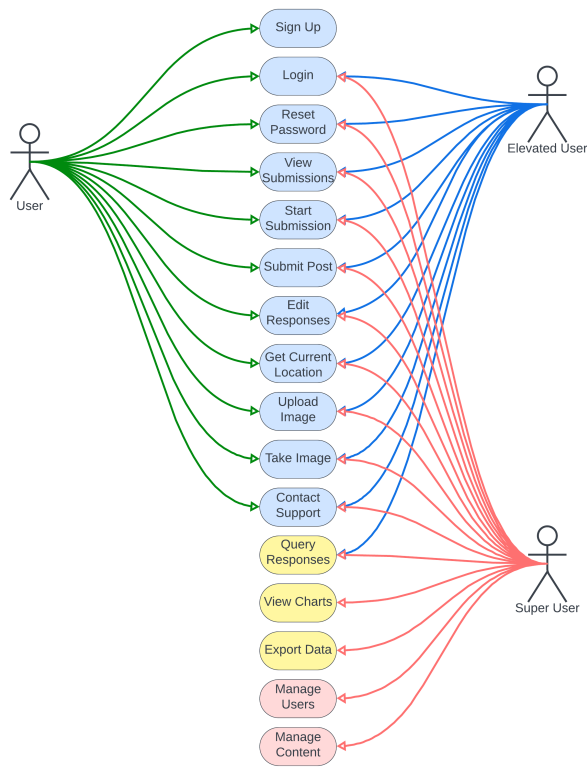


Fig. 1: Diagram showing the detailed use cases and interactions of a user with the TickTrax application. The user, elevated user, and super user are mapped to the use cases as green, blue, and red, respectively.

• UC03 Reset Password

- Users with accounts can reset their passwords either through the website login page or the mobile applications reset password option.

• UC04 View Past Submissions

- Users can view their past questionnaire submissions, while non-account users can view past submissions that are only accessible temporarily.

• UC05 Start Questionnaire

- Users can begin questionnaires by taking or selecting photos, with an option to continue a non-submitted questionnaire.

• UC06 End/Submit Questionnaire

- Upon completing the questionnaire, the user can either end the session or submit the responses.

• UC07 Save/Edit Responses

- Users can edit their responses and save them for submission at a later time.

• UC08 Get Current Location

- Users can get the current location of the photos they have taken to be used as part of the questionnaire submission.

• UC09 Upload Images

- Users can upload images they have taken outside the application, provided they grant the application access.

• UC10 Take Photo

- Users can take live photos of subjects as part of the application feature, granted they give the necessary access.

• UC11 Contact Support

- Users can contact support by filling out a contact form sent to a shared organization.

• UC12 Query Responses

- Elevated Users can search and sanitize responses stored in the database.

• UC13 Export Data

- Super Users can export data for use outside the application, allowing running operations on the data using other tools.

• UC14 View Charts

- Super Users can view charts of the data collected from the responses to visualize the data.

• UC15 Manage Users

- Super Users can view, remove, and set permissions for other users, with at least one super user.

• UC16 Manage Content

- Super Users can manage the content on the application, and updates are reflected for both website and mobile app users.

IV. SOFTWARE DESIGN AND IMPLEMENTATION

TickTrax was developed to ensure a resilient software system capable of dealing with live geographical data and provide real-time reporting. This section presents the fundamental aspects of the system's design and architecture starting with the high-level design of the overall system. The following describes the tick data validation and the process of replicating a comparable software system.

A. High Level Design

A high-level design of this system utilizing a Model-View-Controller (MVC) pattern is shown in Figure 2. The architectural pattern was used in conjunction with Vue.js, APS.NET, and the JavaScript and C# programming languages. The MVC pattern was used to separate the concerns of the application into three components: Model, View, and Controller.

First, the model represents the data and business logic of the application involving the MySQL database to handle the data storage and retrieval. In ASP.NET, the data models are defined as classes representing the database table and able to handle data access in the form of inserting, updating, and/or fetching data. Lastly, the other models associated are Vue.js data models that the User Interface (UI) needs to display and allowing components to update when the data changes.

Secondly, the View is responsible for the presentation of the UI where Vue.js framework is utilized to build the UI and

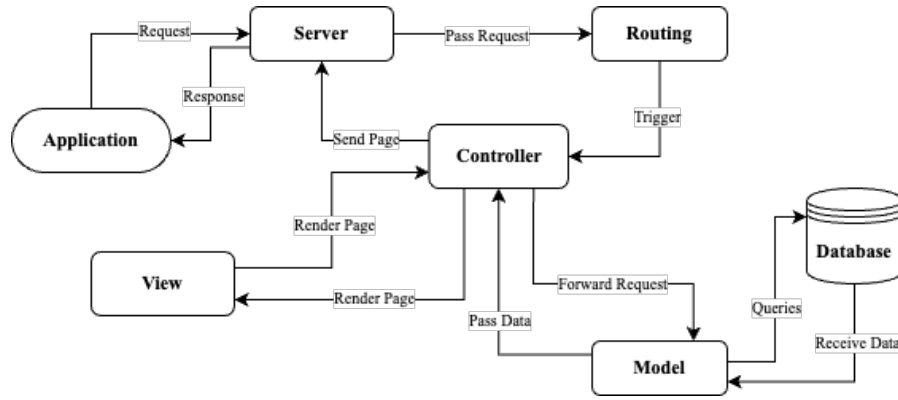


Fig. 2: High-level diagram detailing the architecture of TickTrax utilizing a Model-View-Controller (MVC) pattern.

render the data from the model. The view can then send the user input and interactions to the controller for processing and handling.

Lastly, the Controller acts as an intermediate between the model and the view by handling user input, processing requests, and updating the model. The controller would receive an HTTP request from the view and decide which model to process the data.

B. Technology Utilized

1) *Front End*: The TickTrax's frontend uses Vue.js [11], a widely used JavaScript framework, and by extension, Quasar [12], built on the Vue.js-based framework, utilized to build responsive UI for the mobile and website interfaces of TickTrax. Both technologies were chosen for their user-friendly and intuitiveness enhancing productivity, performance, and consistency in the development process. Quasar's extensive collection of pre-designed and fully functional components proved valuable by reducing the time and effort required during the development cycle. Despite Vue.js' primary focus on web development, the integration of Quasar enabled to extend the support for multi-platform development, including critical software requirements for mobile applications on iOS and Android platforms. The front end uses the exposed endpoints to retrieve data and enable seamless user interaction and a dynamic UI.

The Mapbox Graphics Library (GL) JS [13], a client-side JavaScript library, was utilized to construct the maps within the web application and showcase them through a web browser leveraging the use of a vector format. An advantageous aspect of Mapbox GL JS is its utilization of WebGL for rendering, capitalizing on the graphics processing capabilities of the user's device to facilitate seamless and swift map interactions, particularly when dealing with intricate maps containing vast collections of tick metadata. Moreover, the ability to overlay custom data on the map using GeoJSON enabled us to generate visual representations of data directly on the map as displayed in Figure 3.

2) *Back End*: The TickTrax backend uses several key technologies to ensure efficient data management and seamless

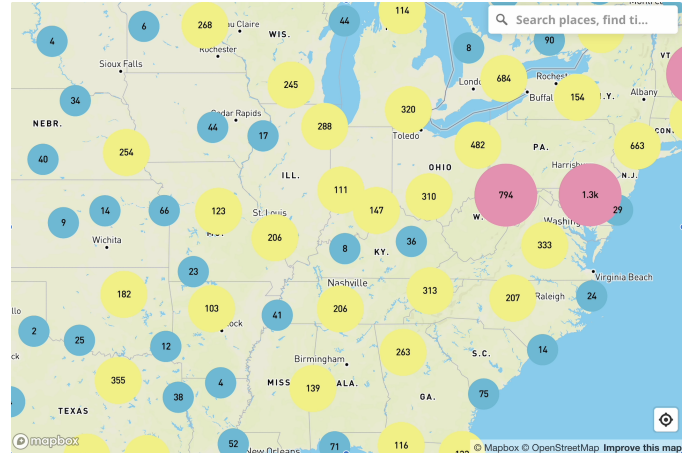


Fig. 3: The map shows geographical data across US locations for tick populations with larger circles signifying higher concentrations of ticks vs smaller circles utilizing the Mapbox API.

user interactions. First, the system utilizes MySQL [14], an open-source relational database, to store and manage structured data effectively. Additionally, to facilitate seamless communication between the front end and the database, TickTrax leverages ASP.NET Core [15], an open-sourced framework, which was implemented as a connection between the front end and database in C#. This framework serves as the foundation for building Application Programming Interface (API) acting as an intermediate between the UI and the back end database. Moreover, back end system is containerized using Docker [16], a containerization platform. Containerizing TickTrax allows for a streamlined deployment process, ensuring that the system can accommodate multiple users independently and securely once hosted.

C. User Interface Design

The user interface for TickTrax contains multiple pages on the mobile and the website application. The role of the user (citizen, researcher, or system administrator) will reflect the different levels of access and features they may utilize.

The web application following an initial sign up and sign in page contains four top-level pages including a home, form, map, and an accounts page. The home page contains relevant information on ticks such as bite prevention, symptoms of tick-borne illness, and current research efforts for tick monitoring. The form page contains an upload component where users can upload a photo of the tick and collects the meta-data associated and an option to input the location, date, and time of collection. The map page contains the total number of tick-identifying cases being reported, a map of ticks, and a control panel in which users can filter based on the data they would like to be displayed. The accounts page includes the personal information of the user, including an editing option for their information, and users can report issues within the web application.

The mobile application, displayed in Figure 4, also contains similar features to the website however differs in the information being displayed for a more user-friendly experience and readability of the system. The mobile application currently doesn't allow researchers to download the data into a csv format and the historical trend graphs as a png, svg, or a csv compared to that of the website.

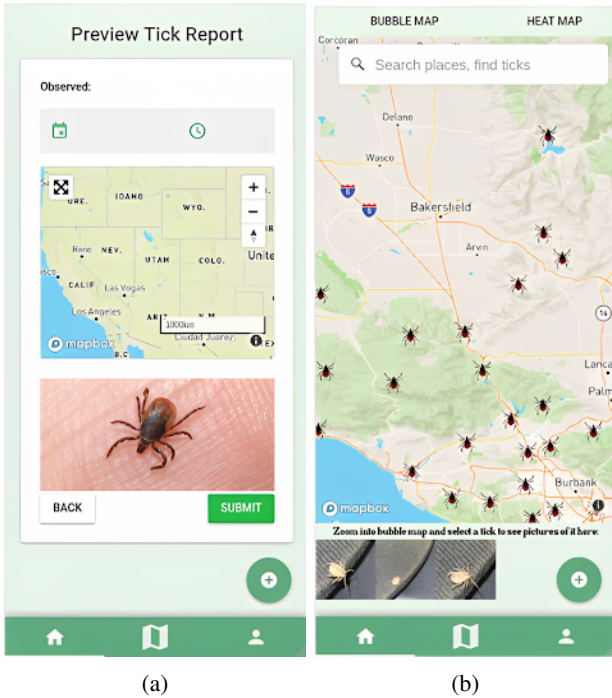


Fig. 4: The mobile UI of TickTrax displays (a) a pre-submitted tick report with a date, time, location, and preview of the tick photo and (b) a map location of registered ticks with a photo preview box.

The tool tips provide informative messages to the user providing clarity and usability to help understand the purpose and functionality of the elements. The loading icons aid in the visual representation of the ongoing process within the application that is operating in the background which assures the user's actions have been acknowledged and that the system

is working as expected. Additionally, form validations ensure that the information provided by the user is accurate, complete, and meets the required format by providing real-time feedback to the user. The scroll bars enhance the user experience by allowing users to navigate through the content that exceeds the visible area by providing a smooth and efficient scrolling experience when dealing with the content of the website.

D. Evaluation Methods and Validation

The evaluation methods for the TickTrax software system are discussed in the following section to address planned validation approaches to discover potential defects of the system and assess whether or not the software performs its intended functionality. Furthermore, the purpose of the TickTrax system is to utilize citizen science to monitor and track tick distribution, although the collected data can provide insight to address potential concerns of tick-borne diseases.

A comparison study of the TickTrax software and an existing solution, TickTracker [17], is shown in Table III. The software systems features of both TickTrax and TickTracker were compared and consisted of tick identification, map functionality, mobile accessibility, website accessibility, educational component, and analysis.

TABLE III: Feature Comparison of TickTrax vs TickTracker

Features	TickTracker	TickTrax
Tick Identification		x*
Map Functionality	x	x
Mobile Accessibility	x	x
Website Accessibility		x
Educational Information	x	x
Data Analysis		x
Social Platform	x	

Both TickTrax and TickTracker contain similar features such as a map functionality to locate ticks, and a mobile UI for Android and iOS devices, and both software systems contain an educational component related to ticks and tick-borne diseases. However, TickTracker contains a social media platform integrated into their mobile application compared to that of TickTrax. In comparison, TickTrax features contain an accessible website, an analysis portion to graph data, and partial implementation of tick identification. The tick identification feature is further discussed in the future work of this paper alongside the aforementioned features in Table III.

V. CONCLUSION AND FUTURE WORK

A. Conclusion

TickTrax presents itself as an innovative technology that applies the power of mobile/desktop devices and geolocation services to monitor tick populations in real-time. This application provides an approach to monitoring and reporting. Crowdsourcing data from different regions of the globe gives users an accessible source to high-risk areas and a better understanding of tick distribution.

The development and implementation of TickTrax is a step toward addressing the lack of tick monitoring in the US. The

application provides a user-friendly platform to record, monitor, and learn about tick sightings, fostering greater awareness and preventative efforts. TickTrax can ultimately positively impact user understanding of tick habits, high-concentration areas, and best practices for personal protection.

The application employs real-time mapping and data visualization that can be issued to identify tick-prone regions and other regions of interest for the users. This feature enhances user engagement and facilitates the collection of geospatial data to refine our understanding of tick distribution patterns and may aid in public health initiatives. Overall, TickTrax showcases the synergy between technological innovation and public health thus enhancing our capacity to mitigate the impact of tick-borne illnesses in human and animal populations.

B. Future Work

The work in this project created a user-friendly platform for users involved in the crowd-sourcing of data but also the researchers who need the data for further analysis. However, software features can be further developed to benefit the users of TickTrax.

TickTrax does not fully employ the use of machine learning to easily identify ticks in photos submitted to the database. Incorporating a machine learning algorithm to predict a wider variety of tick species would provide a more accurate risk assessment for users. This application also does not integrate a social platform for users to interact with. Having the option to share experiences with other users could further help the efforts of creating community and promote the exchange of insight.

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