Water Quality Monitoring Application

Scope Analysis and Scenario Analysis:

The goal of this project is to develop a Qt-based desktop application that visualizes water quality data for the UK/EU. The application aims to provide insights into pollutant levels and compliance with safety standards across water systems. It allows users to explore trends over time and assess geographic patterns. The target audience spans technical experts, policymakers, and the public who require clear and accessible visualizations, such as tables and graphs, to interpret the data effectively. This application is particularly important within today's environment since there has being growing concern surrounding the quality of water especially within the UK as sewage and pollution are proving to be a major challenge the UK's waterways face.

The application must accommodate diverse user needs, offering an intuitive interface, clean layout, and robust accessibility features. Ensuring usability for both technical and non-technical users is essential, as is supporting those with visual impairments or limited technical knowledge.

Iteration 1

Dashboard

The first iteration focused on creating the core structure of the application. The dashboard was designed to link to empty pages and include essential elements like a header and footer that connected users to important resources such as UK/EU regulations and environmental standards, as referenced. This initial setup ensured that the dashboard was functional and informative from the start.

A key design decision in this iteration was replacing traditional buttons with interactive cards, which enhanced the visual appeal and usability. Each card linked to a different pollutant category, enabling users to easily navigate to specific data. Additionally, hover effects were added to improve user interaction. Although the structure was basic, it set the foundation for future enhancements.

Pollutant Overview

In this iteration, the Pollutant Overview Page was built using a simple QTableView to display pollutant data from a static CSV file. Key columns included sampling points, dates, pollutant names, results, units, and compliance status. A search bar was added to enable users to filter data based on specific terms.

To help users understand compliance, a traffic light color scheme was introduced. This color coding indicated whether pollutant data met safety thresholds. While this iteration was functional, it lacked advanced features such as interactive charts and dynamic updates. Challenges included non-functional search due to parsing errors and performance issues when loading large datasets.

Persistent Organic Pollutants (POPs)

The POPs Page introduced a QTableView to display pollutant data, enabling users to filter by pollutant name. Compliance indicators using a traffic light color scheme were included, but the page's functionality was limited. Significant research was conducted on compliance thresholds, particularly for PCBs and other persistent organic pollutants, ensuring the data was aligned with regulatory standards. Performance optimizations were necessary for larger datasets, and visualizations needed further development.

Environmental Litter Indicators

The Environmental Litter Indicators Page used a QTableView to display data on litter types, water types, locations, dates, and compliance. A search box and QComboBox were implemented to filter the data by specific terms and combinations. However, this iteration lacked advanced interactivity, and performance improvements were needed. These issues were addressed in subsequent iterations.

Fluorinated Compounds

This page displayed fluorinated compounds data in a QTableView, with a predefined compliance threshold of 0.1 μg/L. A search box allowed users to filter the data, but no dynamic charting features were implemented at this stage. Optimization was required for large datasets and future interactivity.

Compliance Dashboard

The first iteration of the Compliance Dashboard involved setting up a table to display all rows from the CSV file. Basic dropdown filters for location, pollutant, and compliance status were introduced but were not fully functional at this stage. The focus was on building the page's structure.

Next Steps:

- Improve data handling for large datasets to ensure better performance.
- Enhance user interactivity by adding charts and dynamic updates.
- Optimize search functionality and ensure filtering works properly.

Iteration 2

Dashboard

Iteration 2 focused on improving the dashboard's data handling. The initial method of loading a static CSV file for each page was inefficient, so the CSV file was modified to load once and be distributed across all pages, improving performance and memory usage. A custom CSV upload feature was introduced, allowing users to upload new datasets. Additionally, each card now included a traffic light compliance indicator, providing a quick, easy-to-understand status of water quality.

Pollutant Overview

In this iteration, the Pollutant Overview Page was improved with interactive bar charts to visualize pollutant trends over time. This change allowed users to compare pollutant levels across different sampling points and dates. Despite these improvements, data clustering in the charts became an issue, especially when displaying large volumes of data. Feedback highlighted the challenge of ensuring consistency in compliance color-coding across the application.

Persistent Organic Pollutants (POPs)

The second iteration of the POPs Page featured line charts to show pollutant trends. A dropdown menu allowed users to filter data by specific sampling points and dates, providing more dynamic and interactive visualizations. However, challenges with chart cluttering arose when too much data was displayed at once, leading to suggestions for breaking the data into segments.

Environmental Litter Indicators

This page was enhanced with interactive bar charts to show trends in litter levels over time and across locations. The dropdown functionality was expanded to group data by date, offering more flexible data exploration. Despite these improvements, chart cluttering remained an issue when large datasets were visualized, prompting further improvements in iteration 3.

Fluorinated Compounds

The Fluorinated Compounds Page introduced line charts for displaying trends in fluorinated compound concentrations. Compliance thresholds were marked clearly on the charts, helping users understand whether the compound levels were within regulatory limits. Feedback indicated that chart clarity could be improved by limiting data displayed at once, which was addressed in iteration 3.

Compliance Dashboard

The Compliance Dashboard saw improvements in its filtering functionality, making it easier for users to filter data by location, pollutant, or compliance status. Additional details on non-compliant pollutants were introduced through an info panel, providing context on the causes and historical trends. Although still incomplete, this feature laid the groundwork for future enhancements.

Next Steps:

- Address chart cluttering and optimize for large datasets to prevent overwhelming users.
- Improve chart interactivity by adding zoom and segmenting data into more manageable pieces.
- Refine compliance indicators for consistency across different sections of the application.

Iteration 3

Dashboard

Iteration 3 focused on refining the dashboard's data handling. The custom CSV upload feature was improved, but the challenge of dynamically updating the cards, particularly for the compliance calculation, was not fully resolved. However, the foundation for future improvements was set. Additionally, language support for both English and French was introduced, laying the groundwork for future localization.

Pollutant Overview

The Pollutant Overview Page was restructured to display data in multiple, less cluttered graphs, helping users focus on individual pollutant trends without being overwhelmed. Some minor adjustments were still needed, including scaling issues to ensure all data could be displayed effectively.

Persistent Organic Pollutants (POPs)

In this iteration, the POPs Page was improved by adding a threshold line in the charts to represent critical compliance levels, making it easier for users to visually compare pollutant levels against safety thresholds. A new dropdown menu format was introduced to improve the selection of sample points and dates, making the data more accessible and easier to analyze.

Environmental Litter Indicators

The charts on this page were refined to be more responsive, and the filter functionality was improved, allowing users to select litter types and water sources more easily. Multiple graphs were added for each dropdown selection, helping users compare litter levels across locations.

Fluorinated Compounds

This iteration focused on refining chart readability, ensuring they were neither too cluttered nor too zoomed-in. Tooltip pop-ups were simplified to provide only essential information, making them more user-friendly. A parsing issue was also identified and fixed, ensuring proper dropdown functionality.

Compliance Dashboard

The Compliance Dashboard saw further refinement, with the filtering functionality becoming more robust and search features working seamlessly across all fields. While the functionality was generally well received, users suggested further improvements to the presentation of non-compliant pollutants.

Next Steps:

- Finalize dynamic updates for compliance calculations and ensure that data is updated correctly across all pages.
- Complete localization features to support full language adaptability for broader user access.
- Continue improving interactivity in charts and data visualizations to provide a more fluid user experience.

User Interface Design, Evaluation, and Iterative Improvement

Application of UI Theory:

The design of the Water Quality Monitoring Application was primarily driven by the principles of user-centered design (UCD), aiming to create an accessible, intuitive, and seamless experience for users interacting with complex environmental data.

- Consistency: A uniform design language was established to ensure consistency across different sections of the application. This includes consistent use of color, font, and interaction patterns, which help users develop a mental model of the application and make it easier to navigate.
- Feedback: Providing users with feedback on their actions was integral to the design. For instance, interactive charts provide real-time updates as users filter data, enhancing the feeling of control and engagement. The compliance indicators also offer immediate feedback, showing whether a pollutant is within safe levels.

- Visual Hierarchy: To guide users' attention to the most important data, a clear visual hierarchy was established. For example, pollutant names, results, and compliance status were made prominent, while secondary details were placed in less attention-grabbing locations.
- Clarity: The application focuses on making complex data clear and easy to interpret. This was achieved by using simple, straightforward layouts for each page and ensuring that visualizations were prominently displayed.
- Consistency: In order to ensure that everyone could easily interpret the data through visualizations such as tables, graphs, and interactive charts, the team used Schneiderman's eight golden rules to ensure that all design elements were consistently met.

By focusing on these principles, the design ensures that users can efficiently navigate between pages, interpret data visualizations, and interact with features like filters and search functionalities.

Prototyping Techniques:
The design process followed a well-defined prototyping methodology, beginning with low-fidelity prototypes and evolving into high-fidelity versions.

- Low-Fidelity Prototypes: The initial phase involved hand-drawn sketches and wireframes that helped brainstorm and visualize the structure and layout of the application. These sketches included basic wireframes of key pages, including the dashboard, pollutant overview page, and compliance dashboard, allowing the team to understand the flow of the application and identify potential layout challenges. Using the low-fidelity prototypes allowed the team to get a clearer understanding of the requirements of the application without investing lots of time discussing the full application.
- High-Fidelity Prototypes: As the project progressed, the prototypes were refined using Qt Designer to build a functional representation of the UI. During this phase, design tools and UI frameworks helped test various components like color schemes, fonts, interactive elements, and charts. These prototypes were vital for identifying usability issues before coding the final application.

The iterative nature of this prototyping process allowed for quick feedback and adaptation, ensuring the final design met user expectations.

Ethics Compliance:
The ethical development of the Water Quality Monitoring Application was a key focus throughout the project. Adhering to ethical research guidelines ensured that user testing and data usage were conducted responsibly.

- User Consent: All participants involved in user testing provided informed consent, ensuring their feedback was used to improve the design. Ethical considerations were particularly important when testing with real users, as the application directly affects decision-making in environmental contexts.
- Publicly Available Data: Since the application uses publicly available environmental data, no explicit consent was required for data usage. However, appropriate attribution was provided, and privacy and transparency were prioritized throughout the project.
- Transparency and Responsibility: The project emphasized the ethical use of environmental data, ensuring that the information communicated through the application was accurate and responsibly presented. This empowers users to make informed decisions about water quality, which aligns with the ethical principles of transparency and accountability.
- Cognitive Biases and Dark Patterns: As a team, we focused on identifying any potential cognitive biases and dark patterns we might unintentionally implement. We determined that dark patterns would not be a concern, as there was no incentive to deceive users into making certain choices. However, we did consider how recent news articles on water quality in the UK might influence the way we present data. To mitigate any biases, the team ensured that raw data was provided, rather than cherry-picking information. We achieved this by researching compliance data and statistics from reputable sources, which were all linked on the home page for users to access and verify the data used in the application.

Evalutation Techniques:

To assess the effectiveness of the application, various evaluation techniques were employed to test its usability, performance, and functionality:

- User Testing: A group of test users, including both technical and non-technical individuals, were asked to interact with the application. The aim was to assess the application's usability, focusing on the clarity of the interface and ease of navigation. Users provided feedback on the functionality of features like filtering, sorting, and data visualization, helping to identify areas for improvement.
- Performance Testing: Given the large datasets the application must handle, performance testing was conducted to ensure the application could render tables and charts smoothly. Different dataset sizes were tested to simulate real-world conditions and ensure the application's scalability. This testing was essential to guarantee that the application would perform reliably even with large environmental datasets.
- Usability Evaluation: Usability evaluations were carried out by observing how users interacted with the application. This process focused on aspects such as navigation ease, data clarity, and the intuitiveness of features like search and filter options. Observations from this evaluation led to refinements in the application to improve its usability.
- Controlled and Field Study: In addition to the above methods, the team employed both a controlled study and a field study to evaluate the application. The controlled study focused on isolated specific features of the UI, like navigation, to ensure all links functioned as expected. This allowed for precise evaluation of user interactions with the system in a controlled environment. The field study was conducted to evaluate the system under real-world conditions. We surveyed the public with our application to test how it performed in less predictable scenarios. The field study proved particularly valuable, providing insights into how easily the application was understood by users with non-technical backgrounds.

Evalution Reasoning:

The evaluation process was designed with specific goals in mind, ensuring that the application would meet both functional and non-functional requirements.

- Dynamic Data Visualization: The decision to use QtCharts was driven by the need to handle dynamic, interactive charts that could visualize large datasets. QtCharts was chosen because it provides the necessary performance and customization options required to create engaging, real-time visualizations.
- Model-View Architecture: The model-view architecture was employed to ensure flexibility and responsiveness. This structure allowed the application to manage varying data inputs efficiently while keeping the user interface reactive to user interactions.

The evaluation techniques were designed to ensure that the application would function seamlessly for a wide range of users and data inputs. By focusing on both user feedback and performance testing, the development team was able to refine the application to meet the needs of its audience while maintaining robust functionality.

Customer Feedback & Integrating Feedback:

Customer feedback played a pivotal role throughout the iterative design process, guiding the development of features and functionality.

- Data Representation: Initial feedback indicated that the data visualization needed to be clearer and more interactive. This led to the inclusion of color-coded compliance indicators and interactive charts that allowed users to explore pollutant trends over time.
- Search and Navigation: Feedback revealed that the search functionality and navigation could be improved. In response, a more robust search process was introduced, allowing users to filter data by fields such as location, pollutant type, and compliance status.
- Prioritizing Simplicity: Throughout the feedback integration process, the focus remained on simplicity and clarity. User input led to improvements in both design and functionality, ensuring the application was intuitive and easy to use for everyone, including those without technical expertise.

Challenged Programmers Faced:

Throughout the development of the application, several challenges arose, especially when handling large datasets and ensuring effective data visualization.

- Handling Large Datasets: One of the most significant challenges was ensuring the application could handle large environmental datasets without performance degradation. Strategies like data preloading and efficient chart rendering were implemented to mitigate this issue.
- Data Grouping and Visualization: Organizing data for effective visualization, particularly when grouping by location and date, required careful design. The data model needed to be structured in such a way that the application could display meaningful trends across different pollutant types and water sources.
- Chart Customization: Ensuring charts displayed accurate trends and were easy to interpret was another challenge. Dynamic chart updates based on user interactions required additional logic and parsing to maintain consistency.
- User Interaction: Making the user interface intuitive and responsive was crucial. Features like dropdown menus, search functionality, and filtering options had to be designed so that users could easily interact with the application and understand the results without confusion.

Features Not Fully Implemented / Partially Resolved:

1. Dynamic Updates for CSV Cards
    - Why Not Achieved: This feature for dynamically updating CSV cards with recalculated compliance data was not completed due to time constraints. The challenge was implementing advanced data binding to handle file uploads and trigger updates.
    - Steps to Complete: Implement a data-binding system that responds to file uploads, enabling real-time updates. This will involve integrating an event-driven framework to ensure data recalculates automatically when a new file is uploaded.

2. Localization Feature
    - Why Not Achieved: Localization was partially implemented for English and French, but full integration was not feasible within the timeline. Not all components were translated, and language support was not fully applied across the UI.
    - Steps to Complete: Finalize text translations and apply language settings across the entire application. Ensure UI elements resize properly to accommodate translations and verify text fitting within layout constraints.

3. Advanced Interactivity (Zooming in Charts)
    - Why Not Achieved: Zoom functionality for charts was planned but not integrated due to time and performance limitations. The charts became cluttered with large datasets, and implementing zoom would require in-depth data handling.
    - Steps to Complete: Revise chart rendering logic to include zoom controls and dynamically adjust data scales. Ensure the feature works smoothly with large datasets by testing many times.

4. Search Functionality Enhancements (Autosuggestions)
    - Why Not Achieved: Autosuggestions were not fully implemented due to time constraints and the complexity of integrating dynamic data retrieval into the search.
    - Steps to Complete: Implement an autosuggestion algorithm that dynamically queries the dataset. This will require integrating asynchronous data fetching to ensure fast response times without impacting performance.

5. Performance Optimization for Large Datasets
    - Why Not Achieved: While optimizations were made, some issues with performance persist, especially when handling large datasets. This includes slow rendering in charts and delays when loading large CSV files.
    - Steps to Complete: Focus on optimizing the data model and chart rendering logic. Test with larger datasets to ensure smooth operation.

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