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Research Paper

Visualizing ocular trauma causes in the philippines: a heatmap analysis

Angelo C. Arguson[1*], Joseph Q. Calleja[2], Geliza Marie I. Alcober[3], Ivan Dwane Gloria[4], Danna May Mansul[5]

[1*]Computer Science, FEU Institute of Technology, Philippines.
[2]Information Technology, FEU Institute of Technology, Philippines.
[3]ISDT, FEU Institute of Technology, Philippines.
[4]Information Technology, FEU Institute of Technology, Philippines.
[5]The Registrar's Office, FEU Institute of Technology, Philippines.

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ABSTRACT

Background: Ocular trauma monitoring in clinics is still relying on manual record-keeping, which constrains real-time data visualization and decision support. Health information systems on the web are one of the possible solutions in enhancing the monitoring of incidents and clinical data in ophthalmology departments.
Objective: To design and test a web-based application to visualize the cases of ocular trauma at the Department of Health Eye Clinic (DOHEC) in East Avenue, Manila, Philippines.
Methods: Descriptive-developmental research design was used. Scrum agile system was used to develop software over a 30-day sprint cycle with project management using Gantt charts. The development tools were Microsoft Visual Studio Code, the XAMPP localhost prototype testing and the CodeIgniter with PHP dynamic web functionality. DOHEC consultants and staff were used to test the beta and identify bugs and mitigate risks in the system. The quality of software was measured by 11 Computing and IT professionals (4 professors, 36.36; 7 industry professionals, 63.63) by the ISO 25010 measuring tool. The Technology Acceptance Model (TAM) was used to evaluate user acceptability by 2 DOHEC consultants. The purposive sampling was utilized. The information was gathered through Google Forms and examined with the help of descriptive statistics.
Result: The mean weighted score of the system based on the ISO 25010 quality instrument was 4.97 out of a possible 5.00 by computing and IT professionals. The weighted mean score of 5.00 obtained by DOHEC personnel using the TAM instrument was the highest possible, which implies that the TAM instrument is completely acceptable by the clinical end-users.
Conclusion: The web-based ocular trauma visualization system developed had a high quality of the software and high user acceptability by both technical and clinical reviewers, which indicated that it was ready to be implemented in an ophthalmology clinical environment.

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Corresponding Author:
Angelo C. Arguson
Computer Science, FEU Institute of Technology, Philippines.
Email: acarguson@feutech.edu.ph

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1. INTRODUCTION

Eye injuries are a major preventable cause of loss of sight, and it is critical to identify the risk factors and characteristics of this occurrence to avoid injuries [1]. Every year, over two million incidents of ocular trauma are reported, with over 40,000 resulting in substantial vision loss [2]. Ophthalmic trauma is associated with various factors, such as the geographic location, culture, and socioeconomic status of the population [3]. Traumatic ocular injury has a negative impact on the patients' and their families' quality of life, as well as their socioeconomic level and psychological well-being [4]. A 15-year retrospective study from Portugal discovered that, in addition to gender and injury location, economic status may be a high-risk driver [5]. In Greece, a 4-year study was conducted and revealed that patients with no formal employment had higher rates of occupational injuries [6]. Interestingly enough, various authors from different nations have benefited from heatmap visualizations as a valuable tool in terms of retinal disease diagnosis software in South Korea [7], posterior pole software in Spain [8], and transcriptional profiling for identifying pathways in retinitis pigmentosa in Germany [9].

In the Philippines, the previous study on ocular trauma was centered on quality of life (QOL) after treatment. This was conducted by University of the Philippines-Philippine General Hospital. The same study revealed that across hospital visits, health-related QOL is at its lowest immediately after injury and improves significantly in the first month [10]. There is a dearth of study presenting the appropriate method of laboratory results for ocular trauma causes in the said country.

The Department of Health East Avenue Medical Center (DOH-EAMC) is committed to provide the highest standard of hospital care in compliance with the statutory and regulatory requirements by continually improving quality management system to the highest satisfaction of our clients. Challenged by their goal, the said healthcare industry agreed to have a joint study with FEU Institute of Technology in 2018.

This paper aims to develop an interactive web-based application that will provide visualizations and efficiently ease the tasks of electronic record data entry operations. The system can efficiently store and manage eye trauma patients' data.

Considering the predicaments stated, this paper sought to answer the following questions:

1) What are the number of patients experiencing ocular trauma in the Philippines?
2) What are the tools and methods needed to develop the system?
3) How will the software provide the visualizations to an ocular specialist?
4) How will the software developed be evaluated by DOH-EAMC Doctors and Computing Professionals?

2. RELATED WORK

2.1. Eyecare Live

An innovative mobile health (mHealth) app connects users with an eye doctor for convenient phone or video consultations and comprehensive vision testing, including specialized dry eye tests and personalized follow-up consultations for contact lens patients. With a range of eye care options, the app ensures that user journeys are tailored to lead individuals to the most suitable destination. Furthermore, the app developer does not collect any data through Android or iOS platforms [11].

2.2. My Chart

This patient portal app offers its users to schedule online appointments, access health records, make payments, and communicate efficiently with their physicians. Widely used by both healthcare providers and patients, this app consolidates all essential patient information in one easily accessible location. The app's icons dynamically respond to user actions, optimizing screen space by presenting more information as users scroll and expand on a new screen. The design organizes numerous navigation items and data, making for a user-friendly and effective product [12].

2.3. Now Serving

This mobile app has access on top Filipino doctors from anywhere in the Philippines. It allows its users to schedule online or in-clinic appointments, receive prescriptions, access lab results, order medications, and more. The Now Serving app seamlessly connects patient with their healthcare providers, ensuring they receive the quality care they deserve. Originally designed to keep the users informed of their queue position [13].

3. METHODOLOGY

3.1. Research Design

A descriptive-developmental approach was employed in this study to develop the system and conduct the study. The authors collected quantifiable information through research instruments for statistical analysis from the inputs of the respondents.

3.2. Respondents and Sampling Technique

The two (2) DOHEC Optical specialists served as the respondents and helped provide useful insights in the development of the system which led to employ convenience sampling method. In addition, eleven (11) computing professionals also served as technical evaluators of the developed systems to ensure it adheres to software quality standards.

3.3. Data Collection and Ethical Concerns

The authors formally coordinated with DOHEC Eye Physicians for software requirement elicitations through emails, face-to-face meetings, and virtual communication channels to ensure data quality along with its confidential structures were handed with consent and that will be protected. Business rules such as policies, profiling forms, and other pertinent documents were obtained from the client to align with the software functional requirements.

3.4. Statistical Treatment

Mean substantially aided in identifying patterns and trends within the survey data set. Using this information to identify areas where the system falls short and areas where it excels would substantially aid in its improvement. The likert scale was intended to more accurately identify and quantify an individual's attitude, opinion, or impression of a particular system. This also helped establish the scope of the system that the end users will have. Frequency and percentage distribution was used to calculate the result of occurrence counts and distribution of percentages of the experience of the respondents about the prototype system.

3.5. Software Paradigm

The developers chose to employ the Scrum developmental approach to design a computing solution. Software development was checked against the schedule of a 30-day sprint along with designated scrum meetings and software requirement backlog reviews. During each sprint, the development team displays progress and receives feedback from the DOHEC Physicians using visual artifacts such as task boards or Gantt charts progress.

3.6. Gantt Chart

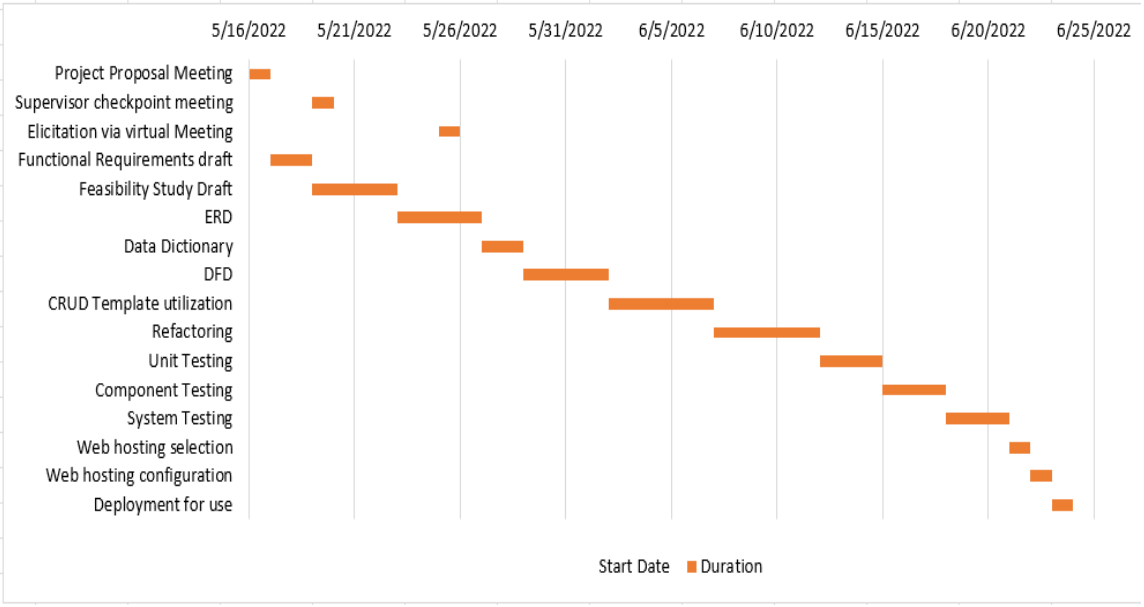


Figure 1. Project Management for the Year 2022

Figure 1 shows the project management results for the year 2022. The development scheme results in providing an initial prototype of the project. Phases noticeably slightly overlap with each other as it is not being directly affected by the DOHEC official's appointments.

Task	Subtask	Start Date	Duration	End Date
System Requirements	MOA Signing	12/14/2022	1	12/14/2022
	Reviewing System Functionality	01/11/2023	1	01/11/2023
	Virtual Mockup with DOH: Initial Dev Presentation	02/01/2023	1	02/01/2023
	Reviewing Blockchain appropriateness	02/05/2023	15	02/20/2023
	Internship Program Application	04/12/2023	1	04/12/2023
	Checkpoint Meeting	04/20/2023	1	04/20/2023
System Design	Entity Relationship Diagram (ERD)	04/13/2023	13	04/26/2023
	Functional Requirements Specification (FRS)	04/13/2023	5	04/18/2023
	Graphical User Interface/Layout	04/27/2023	84	08/03/2023
	Data Flow Diagram (DFD)	04/24/2023	9	05/03/2023
Coding	CRUD implementation	04/24/2023	9	05/03/2023
	Refactoring	04/14/2023	74	06/28/2023
Testing	Unit Testing	04/14/2023	70	07/20/2023
	Component Testing	05/03/2023	74	07/28/2023
	Checkpoint Meeting	18/05/2023	1	18/05/2023
	System Testing	06/05/2023	10	07/28/2023
	Checkpoint Meeting	06/29/2023	1	06/29/2023
Deployment	Finalization of web hosting	07/03/2023	1	07/03/2023
	Web hosting configuration	07/04/2023	2	07/05/2023
	Deployment for use	07/06/2023	2	07/07/2023
	Checkpoint Meeting	07/13/2023	1	07/13/2023
	Online Meeting	07/19/2023	1	07/19/2023
	F2F Testing at DOH East Avenue	08/03/2023	1	08/03/2023
	Turnover	08/14/2023	1	08/14/2023

Figure 2. Project Management for the Year 2023

The Figure 2 shows the project development plan of the final prototype after the dashboard, medical records data entry and heat mapping features were added Figure 2. The steps indicated the system requirements, system designing, coding, testing, and deployment and checkpoint meetings with the DOHEC officials. It can be gleaned from the figure that both graphical user interface (GUI) construction, refactoring, unit testing and component testing were conducted concurrently to meet the needs of the client.

3.7. Evaluation Instrument

For DOHEC respondents to assess the developed system and ensure the quality of the software, the authors provided the technology acceptance model (TAM) as an evaluation instrument. Moreover, the ISO 25010 was selected to evaluate the developed web-based system by the computing professionals.

4. RESULTS AND DISCUSSION

The web-based application was developed by the authors and was able to provide user interfaces that fit the needs of the DOHEC Physicians by following the list of the software requirements. The developer carefully reviewed and followed the instructions on the said listings.

Table 1. Software Beta Testing Results

Requirements	Result
Heatmap display	Accepted
Auto-completion on some fields	Accepted
Barangay suggestions	Accepted
Corrected Ocular trauma jargons	Accepted
Input fields grouping	Accepted
Dynamic field set display	Accepted

As shown in Table 1, the software was tested and approved by the DOHEC Physicians by reviewing the software requirements documented against their software interactions as part of their Checkpoint meeting last August 03, 2023. The end-users tested the software using both smartphones and their laptops to explore the features as suggested during their consecutive virtual meetings.

The developers used web-development tools, starting with Visual Studio Code as source code editor, XAMMP for testing prototypes on computers without any access to the internet, Code Igniter for building dynamic website with PHP, Bootstrap for or developing responsive, mobile-first websites, J Query for event handling, CSS animations and Ajax, ChartJS for visualization, data Tables for enhancing tables in HTML, SVG-Pan-Zoom to enable panning and zooming of an SVG in an HTML document, FPDF/FPDI for reading PDF documents, and Tempus Dominus for date time picker.

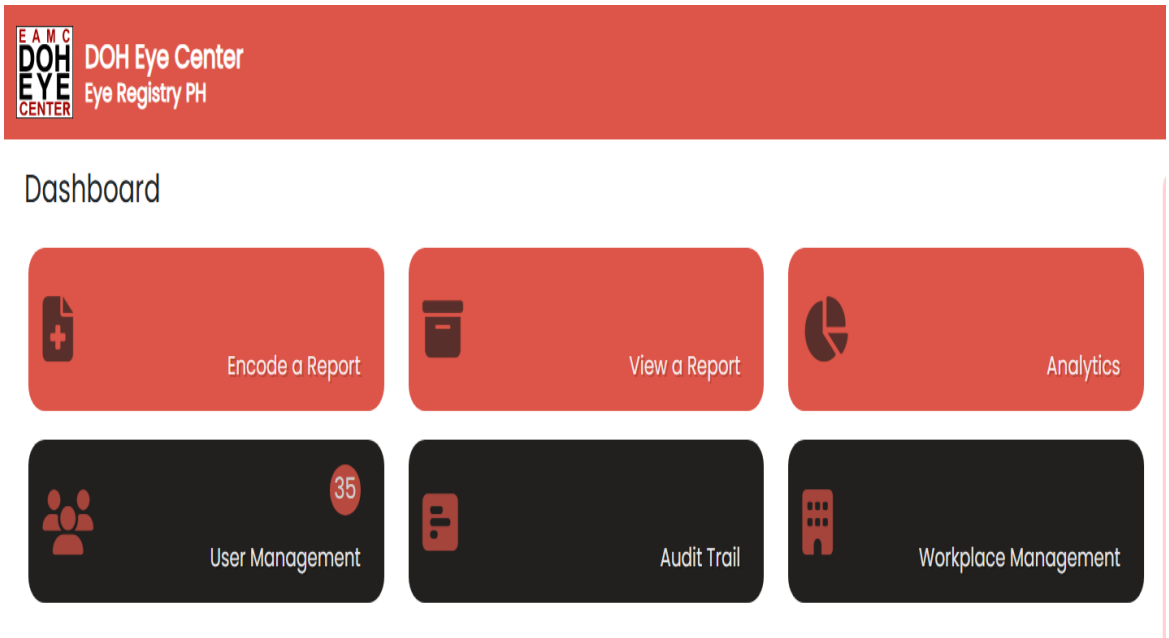


Figure 3. DOHEC Eye Registry Dashboard

After ten (10) months of using the system by its respective end-users, the system was able to provide more data that is very useful in data analysis. The web-based application provides a dashboard to allow users to interact with the system and access the features such as encoding to create reports, viewing reports, view analytics, user management, view audit trails, and workplace management services as shown in Figure 3.

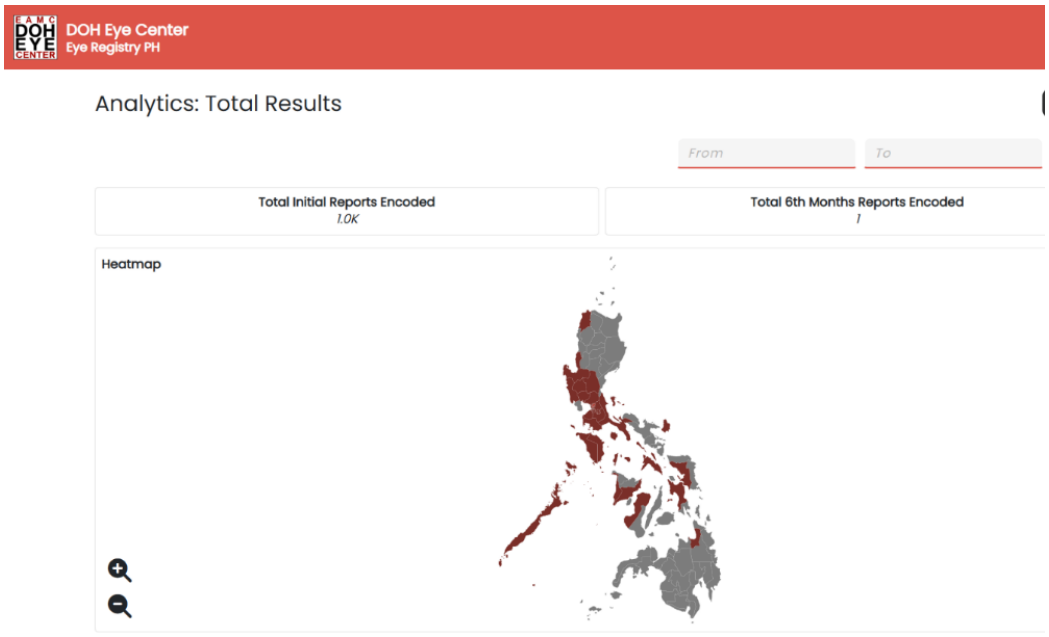


Figure 4. Heatmap Analysis User Interface

The prototype features the provision of heatmap analysis services as shown in Figure 4 which is beneficial to DOHEC administration to monitor and understand the historical data and instances of eye-related injuries. The graphical representation of the occurrences most happens at Luzon and Visayas archipelago despite the distance to DOHEC location. Moreover, the said heatmap visualization was supported by graphs to further analyze the causes and degree of injuries recorded.

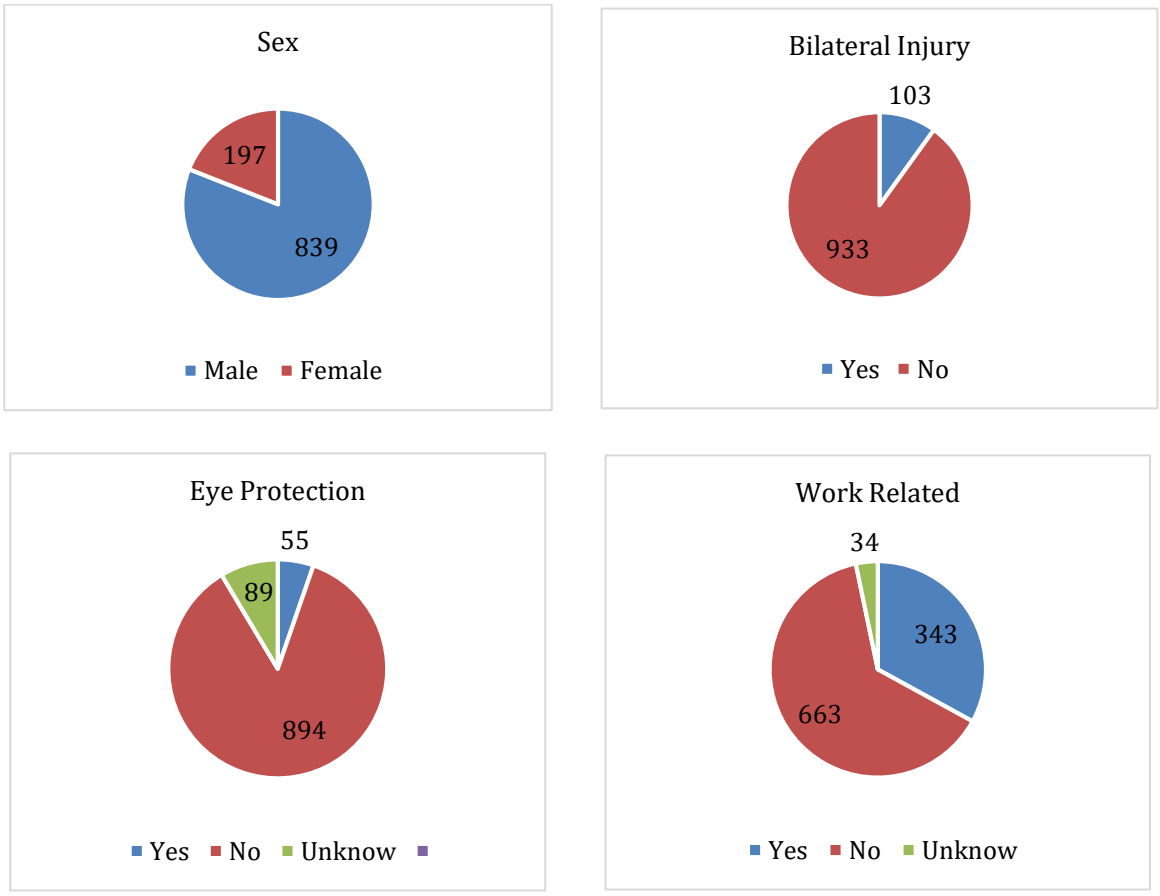


Figure 5. Pie chart Analysis

The web-based application also provides Pie Chart analysis to further review the types of eye injury, gender, work-related, or even experience damage while wearing eye protections Figure 5. The current record shows that there 1036 where 197 or 19% are male and 839 or 81% are female eye patients. The graph also shows that only 933 or 90.05% was not classified as bilateral injury. Injuries occurred while wearing eye protection were only 55 or 5.3%, and 894 or 86.29% for those not wearing them.

Moreover, accidents most of the time occurred outside the workplace 343 or 33.11%, 663 or 64% of them were work-related events, while 34 or 3.28% were classified as unknown.

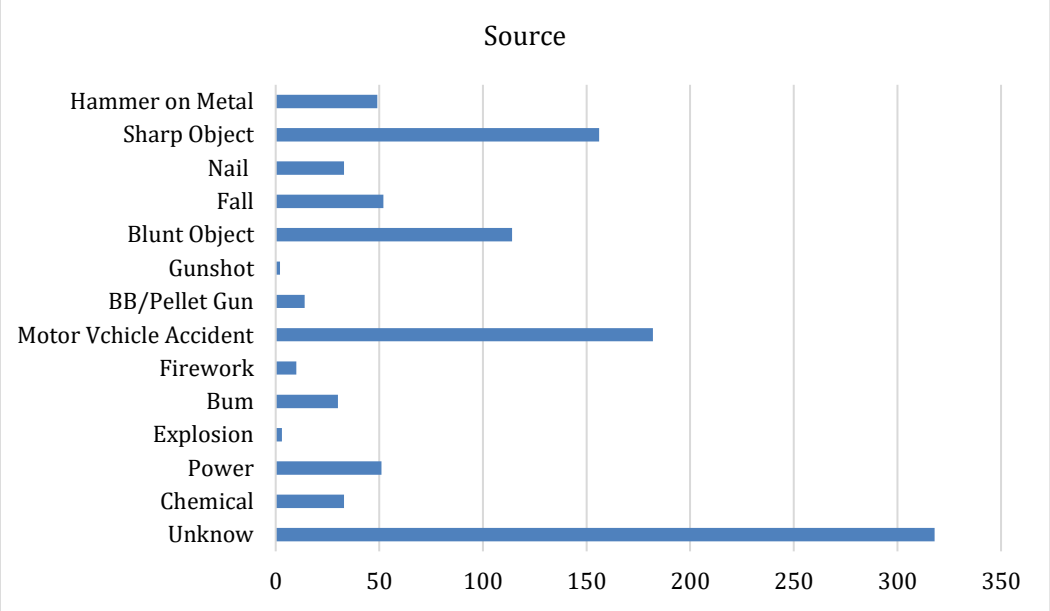


Figure 6. Bar Chart of Eye Injury Sources

Sources of eye injuries can be found on the same web page. It can be gleaned from Figure 6 that the top three of most occurrences were unknown sources 318 or 30.7%, motorcycle accidents 182 or 17.57%, and sharp objects 156 or 15.05%. It can also explain that most of the incidents have occurred outside the known sources that contributes on the influence of the eye injury.

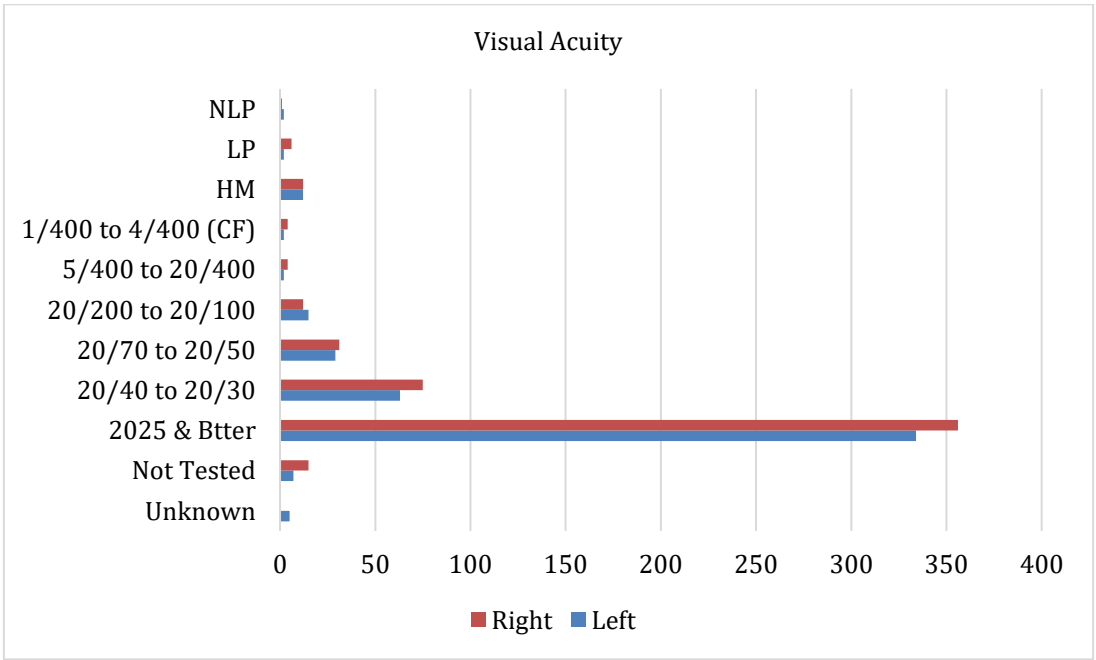


Figure 7. Bar Chart of Eye Tissues Involved

An aggregate visualization regarding tissues involved in the said injury can also be found on the same web page of the application. It can be gleaned from Figure 7 that most occurrences were related to cornea with 537 or 51.83% then followed by lid on a wider margin at 225 or 21.72%.

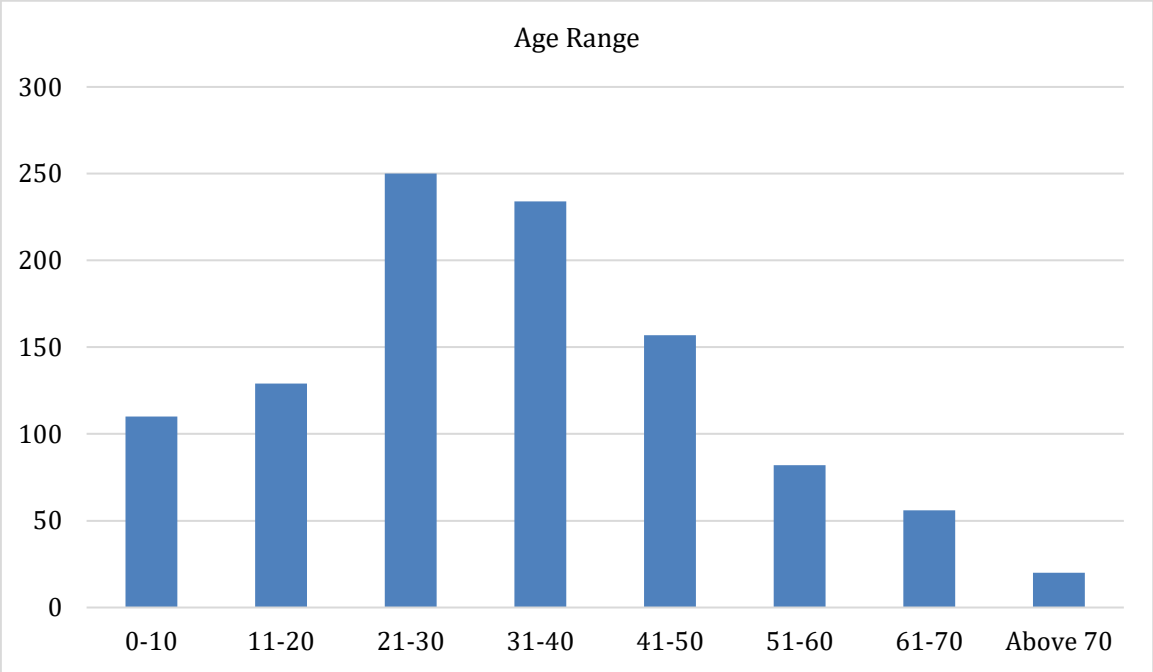


Figure 8. Bar Chart for Visual Acuity

Displaying analytics of visual acuity can also be accessed from the web-based application as seen on Figure 8. The graph displays that most occurrences are "2025 and better" with 356 (34.36%) and 334 (32.24%) followed by "20/40 to 20/30" with 63 (6.08%) and 75 (7.23%).

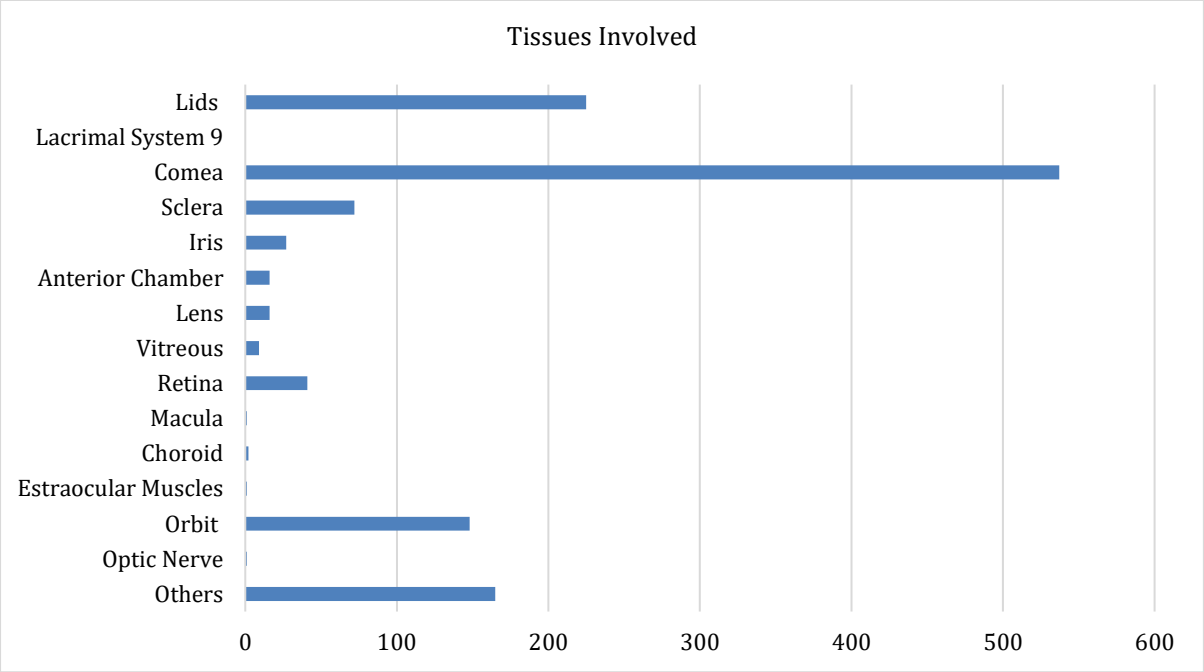


Figure 9. The age range of ocular patients

Figure 9 shows the age range of ocular patients being recorded by the web application was also available on the Analytics page. It can be gleaned from the results that most of the eye patients were young

adults around “21-30 years of age” with 250 instances or 24.13%, “31-40 years old” group age with 234 instances or 22.59% and followed by “41-50 years old” with 157 instances or 15.15% while the lowest was “above 70 years old” group with only 20 instances or 1.93%.



Figure 10. Software Acceptability Evaluation by DOHEC Doctors

The evaluations for software quality and user acceptability succeeded the development phase. There are two (2) DOHEC consultants who participated in the acceptability mainly due to their role in being the focal person to use the said software using the TAM instrument Figure 10.

Table 2. Acceptability Evaluation Results

Item	Mean	Interpretation
Perceived ease of use	5.0	Strongly Agree
Perceived usefulness	5.0	Strongly Agree
Behavioral Intention	5.0	Strongly Agree
Attitude	5.0	Strongly Agree
Self-efficacy	5.0	Strongly Agree
Social Norm	5.0	Strongly Agree
System Accessibility	5.0	Strongly Agree

Table 2 shows the user acceptability evaluation done by the 2 DOHEC officials which are primary users of the developed ocular trauma registration web application. Both evaluators highly recommended the use of the software to augment their work.

Aside from acceptability evaluation, a separate session was conducted by the authors with Computer Science and IT Professionals using ISO 25010 for software quality evaluation. Both were provided screenshots and shown a software use demonstration. The said session involved 11 Computing and IT Professionals, 4 or 36.36% of whom were Professors and 7 or 63.63% of whom were Industry Computing Professionals in user software quality evaluation using ISO 25010 instrument.

Table 3. Software Quality Evaluation Results

Item	Mean	Interpretation
Functional Suitability	4.82	Strongly Agree
Reliability	4.98	Strongly Agree
Performance Efficiency	5.00	Strongly Agree
Usability	4.98	Strongly Agree
Portability	5.00	Strongly Agree
Maintainability	5.00	Strongly Agree

Compatibility	4.95	Strongly Agree
Security	5.00	Strongly Agree

Table 3 shows the user acceptability evaluation done by the 11 CS and IT Professionals of the developed software using ISO 25010 instrument. It can be derived from the table that the majority of the evaluators agree that the software is of high quality and has a low chance of debugging tasks to be done. The Table 3 shows that performance efficiency, portability, and, security, maintainability obtained the highest rating while both reliability and usability tied at the second rank in the rating.

5. CONCLUSION

The authors proved that the web-based ocular trauma with visualization system was efficient in assisting the DOHEC staffs in encoding ocular injury details with either smartphones or laptops. The system was equipped with heatmap and supporting charts that will aid the DOHEC physicians better understand the situation of the patient better and faster. However, the dataset for both evaluations was seen as too limited since the authors wanted to have focus groups to check on the system with the intention of acceptance and deployment faster.

It was therefore noted that this paper tried to address the following questions:

1. What are the number of patients experiencing ocular trauma in the Philippines?
2. What are the tools and methods needed to develop the system?
3. How will the software provide the visualizations to an ocular specialist?
4. How will the developed software be evaluated by DOH-EAMC Doctors and Computing Professionals?

Hence, this section addresses the research questions as follows:

1. There are 1036 ocular trauma occurrences where 19% are male and 81% are female.
2. The developers used web-development tools such as Visual Studio Code, XAMMP, CodeIgniter for building dynamic website with PHP, Bootstrap, JQuery, ChartJS for visualization, dataTables for enhancing tables in HTML, SVG-Pan-Zoom, FPDF/FPDI for reading PDF documents, and Tempus Dominus for date time picker. The software was constructed by adhering to scrum methodology which aids the developers in organizing complex tasks and respond adaptively in short sprints. The Gantt chart really helped the developers with monitoring their progress and upcoming tasks over a span of two (2) consecutive years.
3. Upon successful login as administrator or registered ocular staff, a dashboard will be provided to start the interaction on the preferred visualization. Graphical presentation of certain analytics will be provided viz. heatmap analysis, demographics analysis, eye injury sources, eye tissues involved, and visual acuity.
4. The developed software was evaluated via online and face to face sessions both for the end-users and computing professionals. The majority of the evaluators agree that the software was very satisfactory rating both on software quality and user acceptance.

Recommendation

The authors successfully developed the web-based ocular trauma registration and visualization for analysis. However, there are certain limitations found after the development. With this, the authors would like to recommend the following features for future researchers:

1. A recommender system that prescribes a certain actionable insight based on historical data.
2. A bigger capacity for data server to cater an approximately more than 10 years' worth of data.
3. Dynamic chart selector that will provide visualizations to match the preference of the DOHEC Physicians.
4. Inclusion of visualization in an aggregate form to display heatmap analysis of occurrences per region.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Angelo C. Arguson	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	
Joseph Q. Calleja		✓		✓		✓		✓	✓			✓		✓
Geliza Marie I. Alcober	✓	✓		✓	✓		✓			✓		✓	✓	
Ivan Dwane Gloria	✓		✓	✓		✓	✓	✓			✓		✓	✓
Danna May Mansul			✓		✓		✓	✓	✓	✓	✓			✓

C: **C**onceptualization
M: **M**ethodology
So: **So**ftware
Va: **Va**lidation
Fo: **Fo**rmal analysis
I: **I**nvestigation
R: Resources
D: Data Curation
O: Writing- **O**riginal Draft
E: Writing- Review& **E**diting
Vi: **Vi**sualization
Su: **Su**pervision
P: **P**roject administration
Fu: **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Informed Consent

All participants were informed about the purpose of the study, and their voluntary consent was obtained prior to data collection.

Ethical Approval

The study was conducted in compliance with the ethical principles outlined in the Declaration of Helsinki and approved by the relevant institutional authorities.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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BIOGRAPHIES OF AUTHORS

	**Angelo C. Arguson**, is a faculty member in the Computer Science program at FEU Institute of Technology. His research interests include health informatics, data visualization, web-based systems development, and analytics-driven decision support. He specializes in developing interactive platforms that integrate visualization tools such as heatmaps and dashboards for healthcare applications. In this study, he led the conceptualization, system development, validation, and overall project administration of the ocular trauma visualization system. Email: acarguson@feutech.edu.ph
	**Joseph Q. Calleja,** is affiliated with the Information Technology department of FEU Institute of Technology. His expertise includes software engineering, systems analysis, and database management. He contributed to the system architecture design, coding, testing, and quality assurance of the web-based ocular trauma registry. His professional interests focus on developing efficient, scalable, and secure web applications for institutional and healthcare environments. Email: jqcalleja@feutech.edu.ph

	**Geliza Marie I. Alcober,** is connected with the Information Systems and Digital Technologies (ISDT) program at FEU Institute of Technology. Her academic interests include systems validation, data management, and user-centered software development. In this project, she contributed to methodology formulation, system validation, visualization components, and documentation. She is particularly interested in leveraging information systems to enhance healthcare service delivery and analytics. Email: gialcober@feutech.edu.ph
	**Ivan Dwane Gloria,** is an Information Technology professional from FEU Institute of Technology. His areas of expertise include backend development, database structuring, and analytics integration. He played a key role in software development, data curation, visualization integration, and technical documentation for the ocular trauma heatmap system. His interests include building data-driven platforms that improve operational efficiency in healthcare and enterprise systems. Email: dwaneivan@gmail.com
	**Danna May Mansul,** is affiliated with The Registrar's Office of FEU Institute of Technology. She contributed to data management, documentation, validation processes, and project coordination for the study. Her professional interests include administrative information systems, records management, and institutional data governance. She supports initiatives that integrate technology solutions to improve workflow efficiency and organizational decision-making. Email: dcmansul@feutech.edu.ph