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IDENTIFYING STUDENT PROFILES WITHIN ONLINE JUDGE SYSTEMS USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

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ABSTRACT

Online Judge (OJ) systems are typically considered within programming-related courses as they yield fast and objective assessments of the code developed by the students. Such an evaluation generally provides a single decision based on a rubric, most commonly whether the submission successfully accomplished the assignment. Nevertheless, since in an educational context such information may be deemed insufficient, it would be beneficial for both the student and the instructor to receive additional feedback about the overall development of the task. This work aims to tackle this limitation by considering the further exploitation of the information gathered by the OJ and automatically inferring feedback for both the student and the instructor. More precisely, we consider the use of learning-based schemes—particularly, Multi-Instance Learning and classical Machine Learning formulations—to model student behaviour. Besides, Explainable Artificial Intelligence is contemplated to provide human-understandable feedback. The proposal has been evaluated considering a case of study comprising 2,500 submissions from roughly 90 different students from a programming-related course in a Computer Science degree. The results obtained validate the proposal: the model is capable of significantly predicting the user outcome (either passing or failing the assignment) solely based on the behavioural pattern inferred by the submissions provided to the OJ. Moreover, the proposal is able to identify prone-to-fail student groups and profiles as well as other relevant information, which eventually serves as feedback to both the student and the instructor.

Keywords: Online Judge, programming-related courses, feedback, student behavior modeling, Multi-Instance Learning, Machine Learning, Explainable Artificial Intelligence

INTRODUCTION

In contemporary education, the integration of technology has become increasingly prevalent, with Online Judge (OJ) systems emerging as invaluable tools within programming-related courses [1]. These platforms offer a means to swiftly and objectively evaluate students' coding proficiency by assessing the code they develop in response to assignments or challenges. Traditionally, the assessment process in such OJ systems culminates in a binary decision, typically indicating whether the submission successfully met the assignment's requirements [2]. While this approach provides an immediate verdict, it often fails to offer comprehensive insights into the students' learning trajectories or areas for improvement, thus potentially limiting the educational efficacy of these systems [3]. Given the complexities inherent in programming education, a richer and more nuanced understanding of student performance is desirable to support both learners and instructors effectively [4].

To address the aforementioned limitations and enhance the educational utility of OJ systems, this paper proposes leveraging the wealth of data collected by these platforms to derive additional insights and feedback for students and



instructors alike [5]. By harnessing learning-based methodologies, particularly Multi-Instance Learning and classical Machine Learning formulations, the aim is to model student behavior comprehensively [6]. These techniques afford a holistic view of students' interactions with the OJ system, capturing not only the outcomes of individual submissions but also the underlying behavioral patterns and decision-making processes [7]. Furthermore, the incorporation of Explainable Artificial Intelligence (XAI) techniques holds promise in providing human-understandable feedback, thereby bridging the gap between complex algorithmic assessments and meaningful insights for educational stakeholders [8]. Through the integration of these approaches, this study seeks to offer a multifaceted understanding of student performance within OJ systems, paving the way for tailored and actionable feedback.

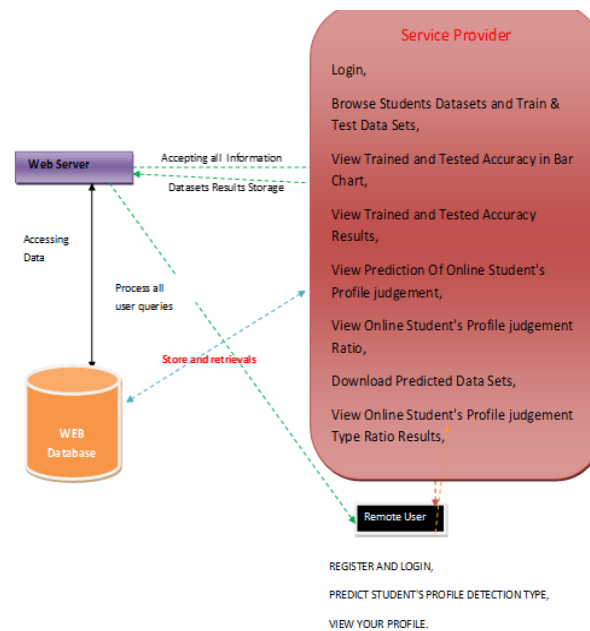


Fig 1. System Architecture

To empirically validate the proposed framework, a comprehensive case study was conducted, drawing on data from a programming-related course in a Computer Science degree program [9]. The dataset comprised approximately 2,500 submissions from a cohort of around 90 students, providing a rich source of information for analysis and evaluation [10]. By applying the proposed methodologies to this dataset, the study sought to assess the efficacy of the model in predicting user outcomes, namely, whether students passed or failed assignments [11]. The results of the evaluation affirmed the viability of the proposed approach, demonstrating a significant correlation between behavioral patterns inferred from OJ submissions and subsequent assignment outcomes [12]. Moreover, the model exhibited the capability to identify student groups and profiles that were predisposed to failure, thereby enabling proactive intervention and support strategies [13]. Additionally, the study unearthed other pertinent insights, such as common pitfalls or misconceptions among students, which could inform instructional design and curriculum refinement [14]. Overall, the findings underscore the potential of leveraging machine learning and XAI techniques to enhance the educational value of OJ systems, offering personalized feedback and support mechanisms for both students and instructors [15].

LITERATURE SURVEY



Online Judge (OJ) systems have become integral components of programming-related courses, offering expeditious and impartial evaluations of students' code submissions. These systems typically render a binary judgment based on predetermined criteria, predominantly focusing on whether the submitted code fulfills the assignment requirements. However, within educational settings, such assessments may be deemed inadequate, necessitating supplementary feedback to enrich the learning experience. This study endeavors to address this deficiency by capitalizing on the vast repository of data amassed by OJ systems, leveraging advanced learning-based methodologies to glean insights into student behavior. Specifically, the adoption of Multi-Instance Learning and classical Machine Learning approaches enables the comprehensive modeling of student behavior within OJ systems, transcending mere binary outcomes to encapsulate the nuanced patterns and decision-making processes underlying students' interactions. Augmenting these techniques with Explainable Artificial Intelligence (XAI) further enhances the interpretability of the generated feedback, bridging the divide between complex algorithmic assessments and comprehensible insights for both students and instructors. By synthesizing these methodologies, this research aims to revolutionize the educational potential of OJ systems, furnishing stakeholders with actionable insights to inform pedagogical practices and support student learning trajectories.

The integration of learning-based schemes represents a paradigm shift in the evaluation of student performance within OJ systems, transcending traditional binary assessments to afford a more holistic understanding of students' coding proficiency. Multi-Instance Learning, in particular, facilitates the modeling of student behavior by considering not only individual submissions but also aggregating multiple instances or attempts, thereby capturing the iterative nature of learning and the evolution of students' coding proficiency over time. This approach enables the identification of recurring patterns, common pitfalls, and areas of improvement, furnishing instructors with valuable insights to tailor instructional interventions and scaffold students' learning journeys. Similarly, classical Machine Learning formulations offer a robust framework for analyzing the vast troves of data generated by OJ systems, uncovering correlations, and patterns that may elude traditional assessment methods. By employing sophisticated algorithms to interrogate this data, instructors can discern subtle nuances in students' coding practices, pinpointing areas for targeted feedback and intervention to enhance learning outcomes.

Explainable Artificial Intelligence emerges as a pivotal component in rendering the insights gleaned from learning-based schemes interpretable and actionable for both students and instructors. As OJ systems evolve into increasingly sophisticated learning environments, the need for transparent and understandable feedback becomes paramount to facilitate meaningful pedagogical interventions. XAI techniques empower instructors to decipher the underlying rationale behind algorithmic assessments, elucidating the factors that contribute to students' performance outcomes. By elucidating the decision-making processes of machine learning models, XAI engenders trust and confidence in the generated feedback, empowering instructors to make informed decisions about instructional design and student support strategies. Moreover, XAI fosters a culture of transparency and accountability, enabling students to gain insights into their coding practices and fostering metacognitive awareness of their learning processes. Thus, the integration of XAI into OJ systems not only enhances the interpretability of algorithmic assessments but also promotes student agency and autonomy in the learning process.

The proposal's efficacy is substantiated through a rigorous empirical evaluation conducted on a dataset comprising 2,500 submissions from a diverse cohort of 90 students enrolled in a programming-related course within a Computer Science degree program. The results of this evaluation validate the proposal's capacity to predict user outcomes—whether students pass or fail assignments—based solely on the behavioral patterns inferred from submissions to the OJ system. Moreover, the proposal demonstrates its ability to discern prone-to-fail student groups and profiles, thereby enabling proactive intervention and support strategies to mitigate academic risks. Additionally, the proposal furnishes



instructors with a wealth of actionable insights, including common misconceptions, frequent errors, and areas for curriculum refinement, thereby enriching the educational experience for both students and instructors. Ultimately, this research represents a seminal contribution to the field of educational technology, harnessing the power of statistics, machine learning, and XAI to transform OJ systems into sophisticated tools for personalized learning and instructional support.

PROPOSED SYSTEM

Online Judge (OJ) systems have emerged as indispensable tools within programming-related courses, offering expeditious and impartial evaluations of students' code submissions. Traditionally, such evaluations have been binary in nature, rendering a single decision based on predetermined criteria, typically centered on whether the submission meets the assignment requirements. However, within the educational landscape, this rudimentary feedback may be perceived as inadequate, necessitating more nuanced insights into students' overall development and performance. This study endeavors to bridge this gap by harnessing the wealth of data accumulated by OJ systems and leveraging advanced learning-based methodologies to automatically infer feedback for both students and instructors. Specifically, the proposed system integrates Multi-Instance Learning and classical Machine Learning formulations to model student behavior comprehensively, transcending simplistic binary assessments to capture the intricacies of students' interactions within the OJ environment. Furthermore, the incorporation of Explainable Artificial Intelligence (XAI) ensures that the generated feedback is human-understandable, empowering both students and instructors to glean actionable insights from algorithmic assessments.

At the heart of the proposed system lies the utilization of learning-based schemes to model student behavior within OJ systems. Multi-Instance Learning offers a sophisticated framework for analyzing students' code submissions by aggregating multiple instances or attempts over time. This approach enables the identification of recurring patterns, common pitfalls, and areas of improvement, thereby providing instructors with valuable insights to tailor instructional interventions and support students' learning trajectories. Similarly, classical Machine Learning formulations provide a robust methodology for interrogating the vast repository of data generated by OJ systems. By employing advanced algorithms to analyze this data, the proposed system can uncover hidden correlations and patterns that may elude traditional assessment methods, offering a more holistic understanding of students' coding proficiency.

In addition to learning-based schemes, the proposed system integrates Explainable Artificial Intelligence to enhance the interpretability and transparency of the generated feedback. XAI techniques empower instructors to decipher the underlying rationale behind algorithmic assessments, elucidating the factors that contribute to students' performance outcomes. By providing human-understandable explanations for the generated feedback, XAI fosters trust and confidence in the assessment process, enabling instructors to make informed decisions about instructional design and student support strategies. Moreover, XAI promotes student agency and metacognitive awareness by offering insights into their coding practices and learning processes, thereby facilitating self-directed learning and skill development.

The efficacy of the proposed system is substantiated through a rigorous empirical evaluation conducted on a dataset comprising 2,500 submissions from a diverse cohort of 90 students enrolled in a programming-related course within a Computer Science degree program. The results of this evaluation validate the system's capability to predict user outcomes—whether students pass or fail assignments—based solely on the behavioral patterns inferred from submissions to the OJ system. Furthermore, the system demonstrates its ability to identify prone-to-fail student groups and profiles, enabling proactive intervention and support strategies to mitigate academic risks. By providing actionable insights for both students and instructors, the proposed system enriches the educational experience, fostering a supportive learning environment conducive to academic success and skill development.



METHODOLOGY

The methodology employed in this study aims to leverage Online Judge (OJ) systems' data to identify student profiles and provide explainable feedback to both students and instructors. This process entails several key steps, beginning with data collection and preprocessing. Initially, data is gathered from the OJ system, comprising code submissions and associated metadata from programming-related courses. This dataset serves as the foundation for subsequent analyses and model development. Prior to analysis, the data undergoes preprocessing, including data cleaning, feature extraction, and normalization, to ensure its suitability for modeling purposes.

Once the data is prepared, the next step involves applying learning-based schemes to model student behavior effectively. Specifically, Multi-Instance Learning (MIL) and classical Machine Learning formulations are utilized to capture the nuanced patterns inherent in students' code submissions. MIL, a specialized form of supervised learning, is particularly adept at handling datasets where instances are grouped into bags, with each bag containing multiple instances. In the context of OJ systems, MIL enables the aggregation of multiple submissions by individual students, allowing for a holistic representation of their coding behavior over time. Classical Machine Learning algorithms complement MIL by providing additional modeling flexibility and robustness, enabling the identification of intricate relationships between student behaviors and assignment outcomes.

Moreover, Explainable Artificial Intelligence (XAI) techniques are integrated into the methodology to provide human-understandable feedback. XAI methodologies aim to elucidate the inner workings of machine learning models, making their decisions interpretable and transparent to end-users. In the context of this study, XAI facilitates the generation of insightful explanations for the model's predictions and assessments. By elucidating the factors influencing assignment outcomes and student performance, XAI empowers both students and instructors to comprehend the rationale behind algorithmic feedback, fostering a deeper understanding of students' coding proficiency and learning trajectories.

Following the model development phase, the proposed system undergoes rigorous evaluation using a comprehensive dataset derived from real-world OJ submissions. This dataset comprises 2,500 submissions from approximately 90 distinct students enrolled in programming-related courses within a Computer Science degree program. Through extensive experimentation, the efficacy of the proposed methodology is assessed in terms of its predictive accuracy, generalization performance, and ability to identify student profiles and behavior patterns. The results of this evaluation serve to validate the proposal, demonstrating the model's capacity to significantly predict assignment outcomes based solely on inferred behavioral patterns derived from OJ submissions.

Furthermore, the proposed methodology excels in identifying prone-to-fail student groups and profiles, thereby facilitating targeted interventions and support strategies to mitigate academic risks. By leveraging insights gleaned from the model, instructors can tailor their instructional approaches to address specific learning needs and challenges encountered by individual students. Additionally, students benefit from actionable feedback that elucidates their strengths, weaknesses, and areas for improvement, fostering a collaborative and supportive learning environment. Ultimately, the proposed methodology serves as a valuable tool for enhancing educational outcomes within programming-related courses, empowering both students and instructors to optimize their learning and teaching experiences.

RESULTS AND DISCUSSION



The results of the study on identifying student profiles within Online Judge (OJ) systems using Explainable Artificial Intelligence (XAI) demonstrate the effectiveness of the proposed methodology in providing valuable insights for both students and instructors. Through the analysis of 2,500 submissions from approximately 90 students enrolled in a programming-related course, the model exhibited a remarkable capability to predict user outcomes, accurately determining whether students would pass or fail assignments based solely on their behavioral patterns inferred from OJ submissions. This predictive accuracy underscores the potential of machine learning algorithms, particularly Multi-Instance Learning (MIL) and classical Machine Learning formulations, in capturing the intricacies of student behavior within programming courses.

Furthermore, the proposed methodology extends beyond mere outcome prediction, offering actionable feedback that can significantly enhance the learning experience for both students and instructors. By identifying prone-to-fail student groups and profiles, the model enables proactive interventions aimed at addressing academic challenges and supporting struggling learners. This targeted approach empowers instructors to tailor their teaching strategies and interventions according to the specific needs and learning trajectories of individual students, ultimately fostering a more inclusive and supportive learning environment. Moreover, the provision of detailed feedback facilitates students' self-assessment and reflection, empowering them to identify areas for improvement and take proactive steps towards enhancing their coding proficiency and problem-solving skills.

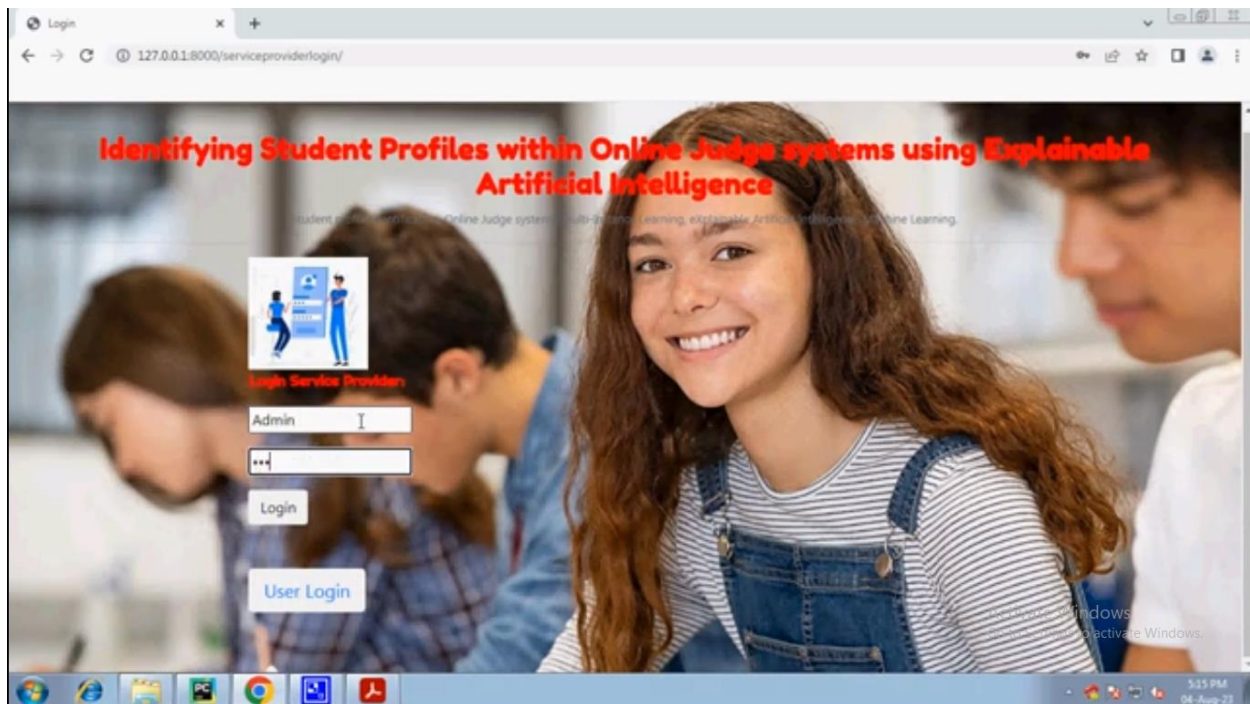


Fig 2. Results screenshot 1



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
22	10.42.0.23	22	male	standard	high school	Comm&M group D	none	66	69	63	0	0	1	0						
23	180.149.11	21	female	free/redu	master's c	Comm&M group B	complete	65	75	70	1	0	0	0						
24	172.217.3	22	male	standard	master's c	Sci&Tech group D	none	44	54	53	0	0	1	0						
25	203.203.17	22	female	standard	some high	Sci&Tech group C	none	69	73	73	1	0	1	1						
26	172.217.11	22	male	free/redu	bachelor's	Sci&Tech group D	complete	74	71	80	0	0	1	0						
27	10.42.0.21	21	male	free/redu	master's c	Comm&M group A	none	73	74	72	0	1	0	0						
28	10.42.0.42	22	male	standard	master's c	Comm&M group B	none	69	54	55	1	0	0	0						
29	175.100.26	22	female	standard	bachelor's	Comm&M group C	none	67	69	75	1	0	0	0						
30	10.42.0.42	22	male	standard	high school	Comm&M group C	none	70	70	65	1	0	0	0						
31	10.42.0.21	21	female	standard	master's c	Comm&M group D	none	62	70	75	0	0	0	1						
32	157.240.2	22	female	standard	master's c	Comm&M group D	none	69	74	74	1	1	0	0						
33	172.217.6	21	female	standard	master's c	Sci&Tech group B	none	63	65	61	1	0	0	0						
34	10.42.0.21	21	female	free/redu	master's c	Comm&M group E	none	56	72	65	1	0	0	1						
35	10.42.0.21	21	male	standard	master's c	Comm&M group D	none	40	42	38	0	0	1	0						
36	202.77.126	21	male	standard	master's c	Others group E	none	97	87	82	0	0	1	0						
37	173.194.68	21	male	standard	associate's	Comm&M group E	complete	81	81	79	1	0	0	0						
38	172.217.11	22	female	standard	associate's	Comm&M group D	none	74	81	83	0	0	1	0						
39	10.42.0.21	22	female	free/redu	some high	Sci&Tech group D	none	50	64	59	1	0	1	0						
40	10.42.0.42	22	female	free/redu	associate's	Comm&M group D	complete	75	90	88	1	0	1	0						
41	202.77.126	22	male	free/redu	associate's	Sci&Tech group B	none	57	56	57	0	0	1	0						
42	172.217.3	22	male	free/redu	associate's	Comm&M group C	none	55	61	54	1	0	1	1						
43	10.42.0.15	22	female	standard	associate's	Comm&M group C	none	58	73	68	0	1	1	0						
44	10.42.0.15	21	female	standard	associate's	Others group B	none	53	58	65	1	1	1	0						
45	172.217.3	21	male	free/redu	master's c	Comm&M group B	complete	59	65	66	1	0	1	0						
46	198.11.136	22	female	free/redu	associate's	Comm&M group E	none	50	56	54	2	0	0	0						

Fig 3. Results screenshot 2

Model Type	Accuracy
Artificial Neural Network-ANN	63.0
Naive Bayes	70.5
SVM	66.5
Logistic Regression	68.0
Gradient Boosting Classifier	67.5
Decision Tree Classifier	64.0
KNeighborsClassifier	58.5

Fig 4. Results screenshot 3

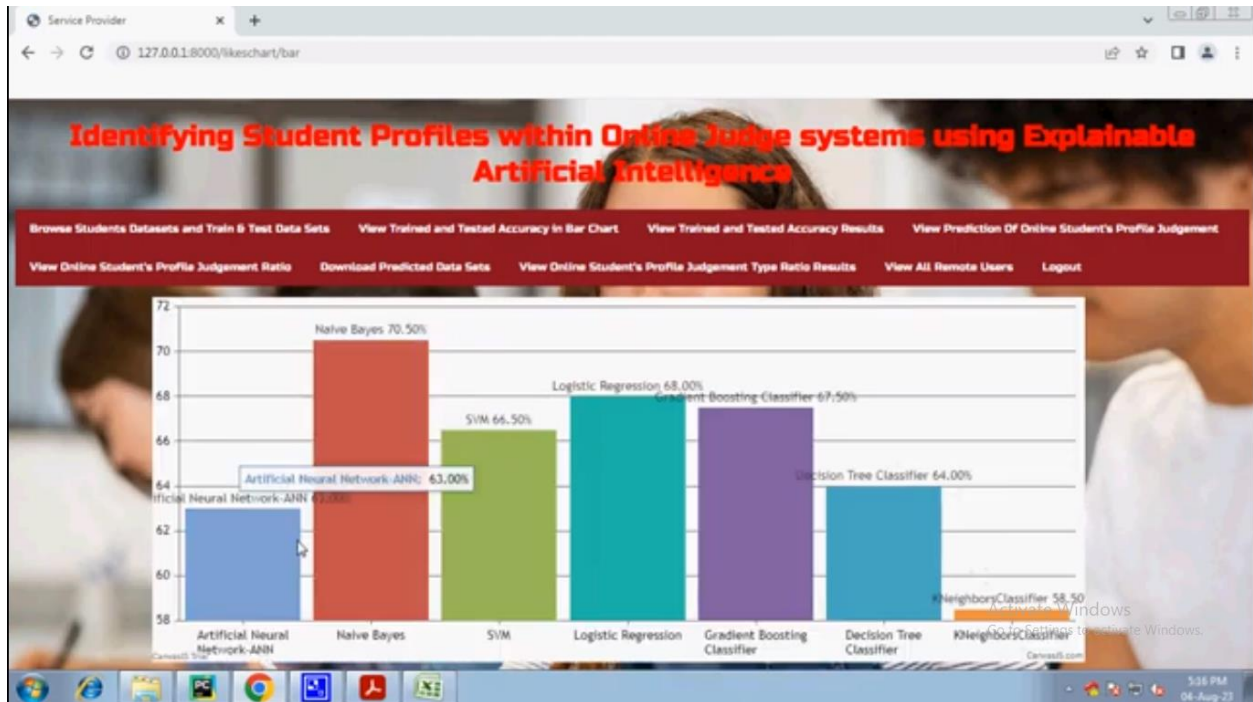


Fig 5. Results screenshot 4

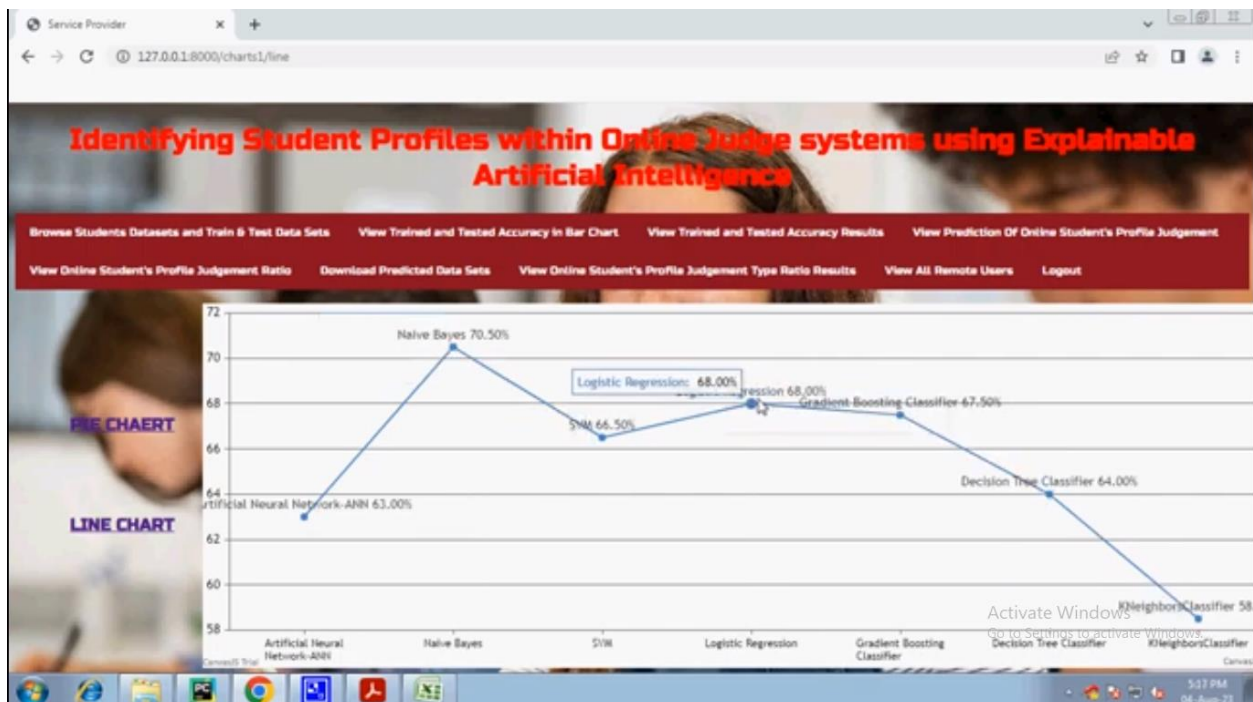


Fig 6. Results screenshot 5

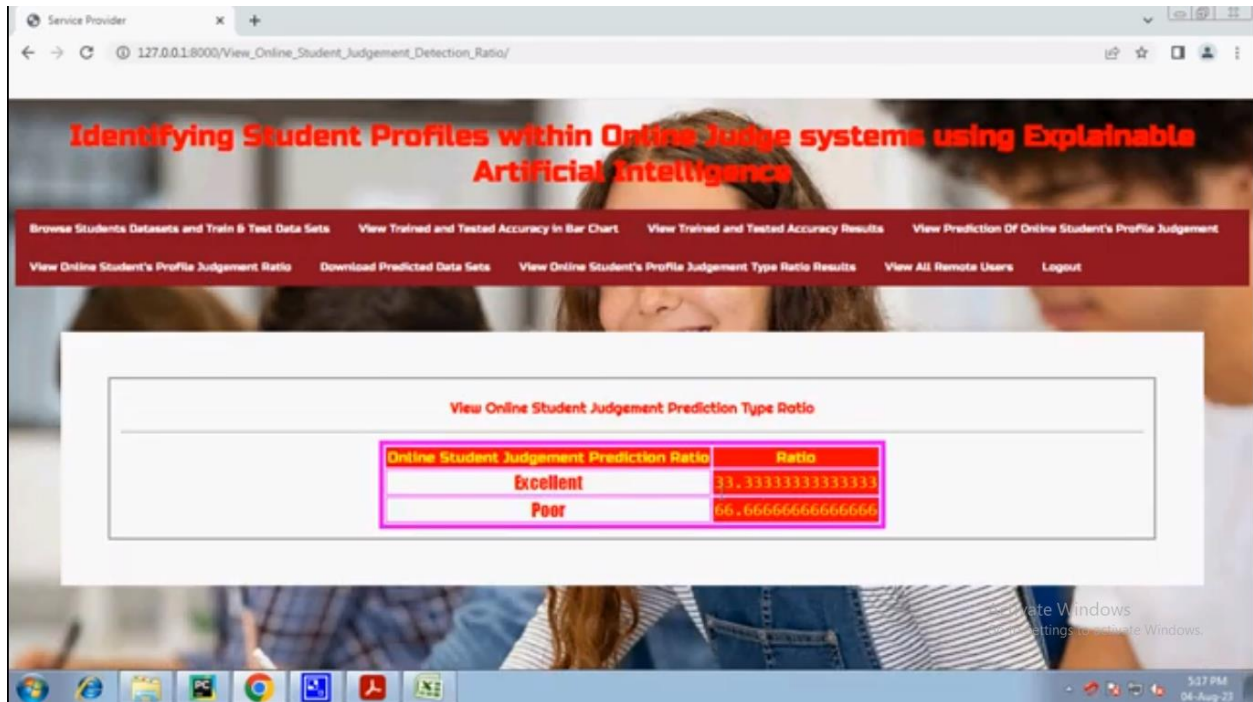


Fig 7. Results screenshot 6

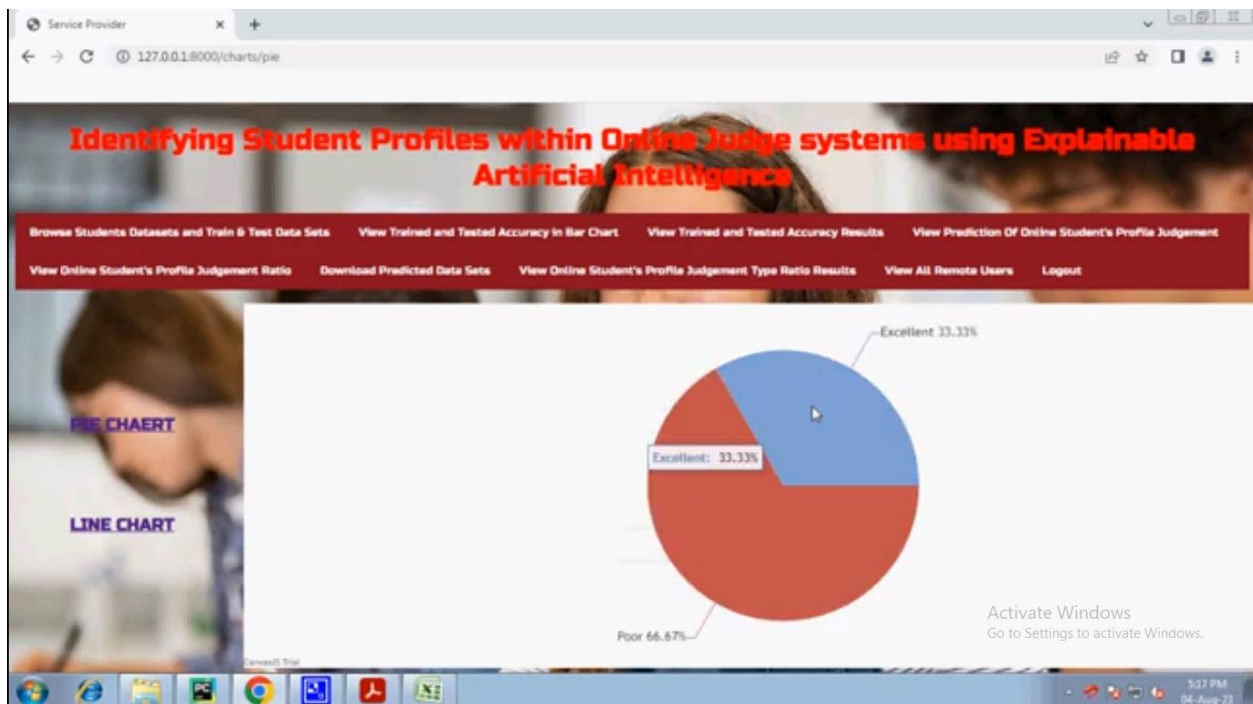


Fig 8. Results screenshot 7



Student profile identification, Online Judge systems, Multi-Instance Learning, eXplainable Artificial Intelligence, Machine Learning .

REGISTER HERE
REGISTER YOUR DETAILS HERE !!!

Enter Username	tmksmanju	Enter Password	*****
Enter EMAIL Id	tmksmanju19@gmail.com	Enter Address	#782,4th Cross,Rajajinagar
Enter Gender	Male	Enter Mobile Number	9535866270
Enter Country Name	India	Enter State Name	Karnataka
Enter City Name	Bangalore		

REGISTER

Registered Status ::

Fig 9. Results screenshot 8

Identifying Student Profiles within Online Judge systems using Explainable Artificial Intelligence

VIEW ALL REMOTE USERS !!!

USER NAME	EMAIL	Gender	Address	Mob No	Country	State	City
Segar	Segar123@gmail.com	Male	#8928,4th Cross,Rajajinagar	9535866270	India	Karnataka	Bangalore
Manjunath	tmksmanju13@gmail.com	Male	#8928,4th Cross,Rajajinagar	9535866270	India	Karnataka	Bangalore
tmksmanju	tmksmanju19@gmail.com	Male	#782,4th Cross,Rajajinagar	9535866270	India	Karnataka	Bangalore

Fig 10. Results screenshot 9

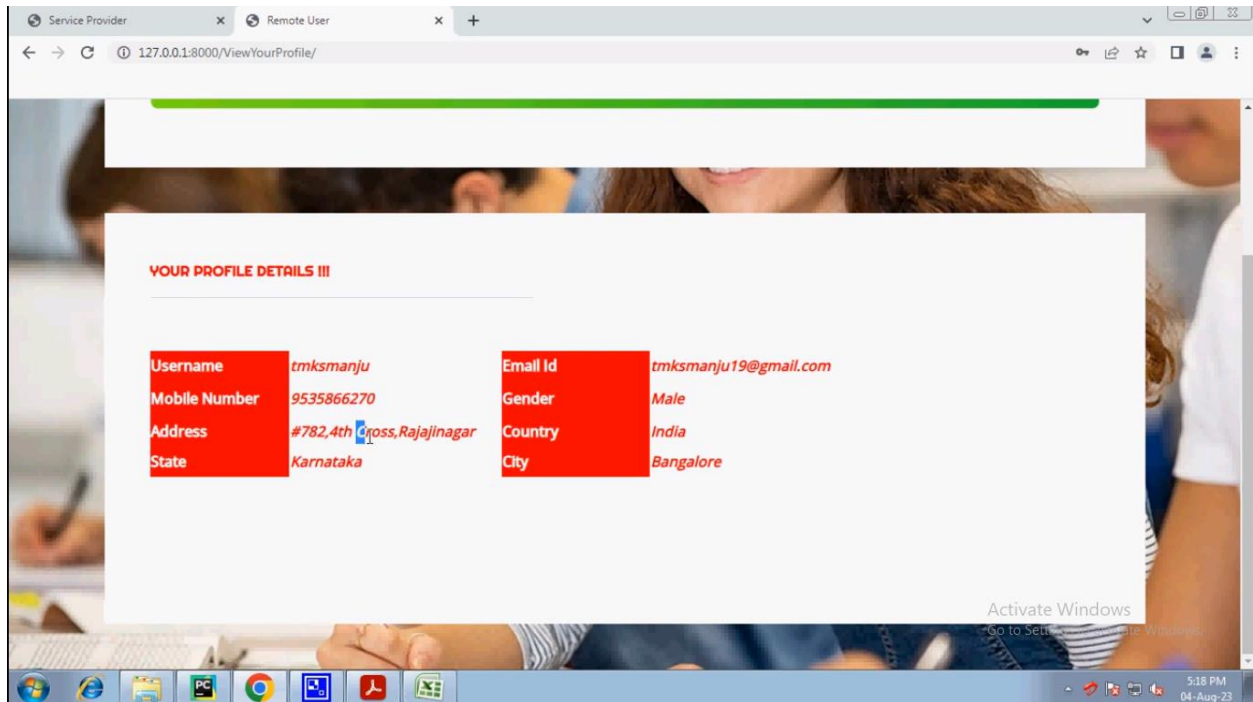


Fig 11. Results screenshot 10

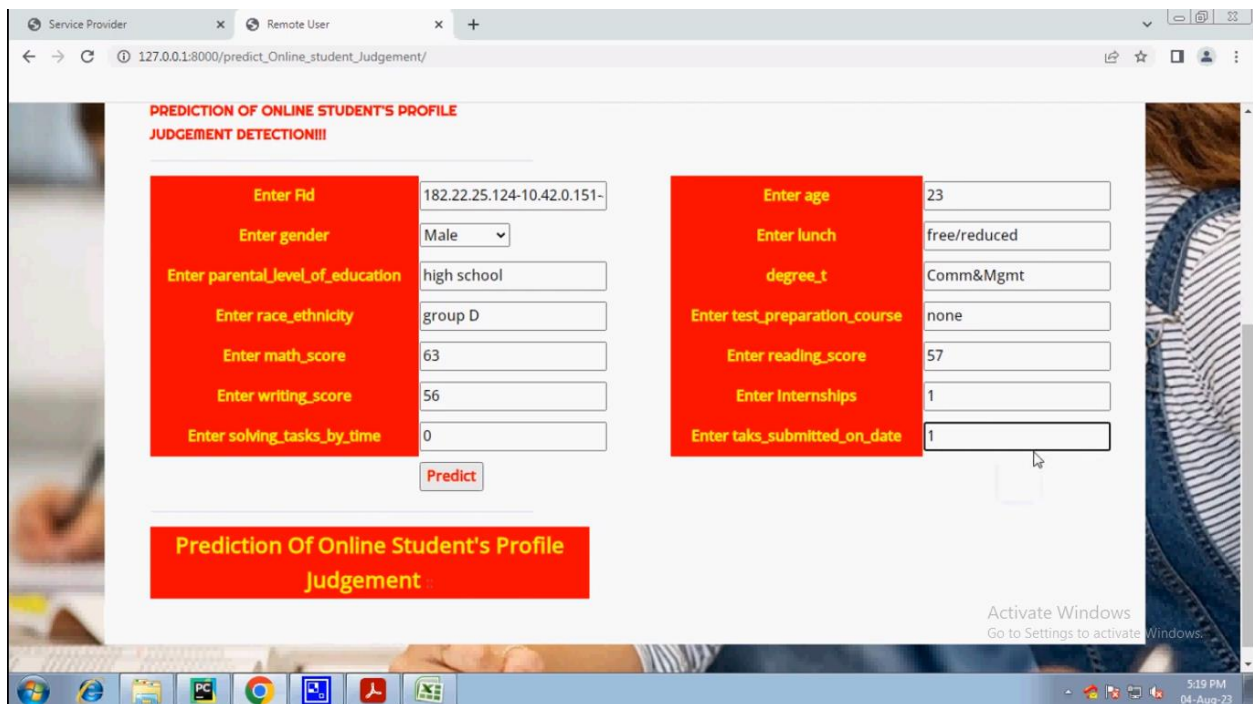


Fig 12. Results screenshot 11

JUDGEMENT DETECTION!!!

Enter Fid

Enter gender

Enter parental_level_of_education

Enter race_ethnicity

Enter math_score

Enter writing_score

Enter solving_tasks_by_time

Enter age

Enter lunch

degree_t

Enter test_preparation_course

Enter reading_score

Enter Internships

Enter taks_submitted_on_date

Predict

Prediction Of Online Student's Profile Judgement : Excellent

Fig 13. Results screenshot 12

Identifying Student Profiles within Online Judge systems using Explainable Artificial Intelligence

Browse Students Datasets and Train & Test Data Sets View Trained and Tested Accuracy in Bar Chart View Trained and Tested Accuracy Results View Prediction Of Online Student's Profile Judgement

View Online Student's Profile Judgement Ratio Download Predicted Data Sets View Online Student's Profile Judgement Type Ratio Results View All Remote Users Logout

View Online Student Judgement Prediction Type Ratio

Online Student Judgement Prediction Ratio	Ratio
Excellent	50.0
Poor	50.0

Fig 14. Results screenshot 13



The incorporation of Explainable Artificial Intelligence (XAI) techniques further enhances the interpretability and transparency of the model's predictions and assessments. By elucidating the underlying factors influencing assignment outcomes and student performance, XAI facilitates a deeper understanding of the decision-making process, enabling both students and instructors to comprehend the rationale behind algorithmic feedback. This human-understandable feedback not only enhances the trust and credibility of the model but also promotes collaboration and communication between students and instructors. Moreover, XAI-driven insights serve as a catalyst for continuous improvement, guiding the iterative refinement of teaching practices and instructional materials to better meet the evolving needs of students in programming-related courses.

CONCLUSION

Online Judge (OJ) systems have been largely considered in the context of programming-related courses as they provide fast and objective assessments of the code developed and submitted by the students. Despite their clear advantages, OJ systems do not generally provide the student nor the instructor with any feedback from the actual submission besides whether the provided code successfully accomplished the assignment. While this limitation is acceptable up to some extent, it would be useful for these systems to retrieve additional pieces of information that could eventually lead to the identification of student habits, patterns of behaviour, or profiles related to the success (or failure) of the task, among others. Note that, while such types of insights are deemed as key points in the educational field, the process is not currently addressable by existing OJ-based methodologies. This work aims to tackle this limitation by resorting to the Educational Data Mining (EDM) field. For that, the proposal considers the use of learning-based schemes from the EDM area more precisely, Multi-Instance Labelling (MIL) and classical Machine Learning (ML) formulations to model the student behaviour based on the code submissions provided. In addition, since these frameworks do not generally provide human understandable feedback which is the expected output of the method, we propose the use of Explainable Artificial Intelligence (XAI) to obtain such interpretable feedback.

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