How Good is the Project Assignment? The Effect of Preference Information on the Quality of Assignment Outcomes.

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2024

Abstract

This research evaluates various preference aggregation methods used in allocation systems. Utilising data from the School of Informatics at the University of Edinburgh, student interviews, and a developed web-based survey, this research assesses the effectiveness of four preference aggregation methods: Rank, Rank Score, Group, and Approval. By applying principles from social choice theory and efficiency metrics, the study evaluates the fairness and efficiency of these methods. Findings indicate that the Group method consistently results in a higher percentage of students receiving their preferred projects, suggesting its effectiveness in representing individual preferences. The Rank & Score method, while aligned with current practices in the School of Informatics at the University of Edinburgh, also performs well but is more time-consuming. This study highlights the potential benefits of adopting a Group approach to enhance the matching of allocated projects with student preferences. The results encourage the School of Informatics and other institutions seeking to optimize project assignments, to further research these methods to refine and potentially improve allocation systems.

Research Ethics Approval

This project obtained approval from the Informatics Research Ethics committee.
Ethics application number: 205195
Date when approval was obtained: 2024-06-05
The participants' information sheet, a consent form, and online consent form are included in the appendix.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Belle Watt*)

Acknowledgements

I would like to thank Aris Filos-Ratsikas for supervising and proposing the project. Thank you to Sreedurga Gogulapati for helping me through many difficulties while my supervisor was on leave. A special thank you to my parents, Karl and Jennifer Watt, for letting me pursue my master's and being supportive throughout all my studies.

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Chapter 1

Introduction

1.1 Motivation

Preference aggregation is a protocol that participants follow to elicit their preferences, where the outcome is determined by an allocation [18]. The need for fair and efficient preference aggregations is crucial given the wide variety of domains in which they are used to make decisions. Educational institutions will use preference aggregation and allocation algorithms to match students with projects, schools, and supervisors [42]. The job market employs these methods for medical students to determine which hospitals and specialties they will be allocated for their residency programs [53]. One familiar preference aggregation is the classic voting systems used for government elections, which will determine the political outcome [5].

Social choice theory is applied in scenarios with preference aggregation and allocation systems to analyse the collective outcome to determine the fairness [64]. This theory has been used to examine different preference aggregations to identify which protocols produce the best outcome for all participants [52]. Social Choice remains a continued line of research in multiple domains of computer science and artificial intelligence, aiming to create fairer outcomes in these fields [16].

At the School of Informatics at the University of Edinburgh, students are allocated dissertation topics based on their ranking of project preferences from 1-5 [47]. This scenario demonstrates a one-way matching algorithm, where students express preferences over projects, highlighting the importance of the protocol used to collect these preferences [26]. Many students, as noted in interviews found in Appendix F, have expressed concerns regarding the limited influence they feel they have over their dissertation topics. Some have indicated that the current preference aggregation system does not always align well with their timelines. This can sometimes lead to a sense of disengagement and diminished motivation in completing their dissertations. These observations suggest there may be room for improvement in the current allocation process, particularly in how it addresses student preferences. This research aims to explore this area further by examining various preference aggregation methods to identify a protocol that more effectively captures student preferences.

Analysing preference aggregation devices will allow for future participants in allocation systems to have a better representation in the outcome. Reviewing this issue at the School of Informatics at the University of Edinburgh could enable students to have more trust in the allocation system, potentially increasing motivation and interest in their dissertations. Furthermore, insights from this research can contribute to the broader field of preference aggregations and social choice theory, aiding in the creation of more efficient and fair outcomes across various domains.

1.2 Objective

This research aims to define different preference aggregation protocols and analyse which protocol allows for the most fair outcome, focusing on social choice theory. The study addresses two important questions: Which preference aggregation protocols allow for efficient and fair outcomes? And secondly, how can the School of Informatics improve its allocation process? The objectives include evaluating various elicitation devices to determine how accurately each device captures student preferences in the project allocation outcome. By implementing allocation algorithms, including the one used by the School of Informatics at the University of Edinburgh, the research will analyse the performance of each algorithm across all datasets. The efficiency and fairness of each elicitation device will be scrutinized to assess whether the current system at the School of Informatics at the University of Edinburgh is fair and efficient, or if an alternative preference aggregation could significantly improve the allocation. The main goal is to identify potential enhancements to the project allocation process by determining whether the most efficient and fair preference aggregations are being applied, thereby contributing to more effective project allocation outcomes.

1.3 Summary of Results

The analysis of student feedback in Appendix F and the data analysis suggest that there may be a more effective preference aggregation method than the one currently used by the School of Informatics at the University of Edinburgh. To potentially enhance the efficiency and fairness of the allocation process, it could be beneficial for the School to explore a system where students express their preferences in groups. Grouping, has demonstrated a lower average distortion, and allocates a higher number of students to their top-choice projects. This suggests it may be a fairer and more efficient protocol. Additionally, survey participants indicated that grouping has a low execution time and allows for easier expression of preferences. While these findings point to the potential advantages of grouping over ranking, further research and consideration of different algorithms are recommended to determine the best approach for this context.

1.4 Structure of the Document

This dissertation is structured as follows: Chapter 2 provides the necessary background and related work relevant to this topic. Chapter 3 outlines the methodology used to conduct the research, including the research design and data collection methods. Chapter 4 details the implementation of the research, including software and method execution. Chapter 5 presents the analysis of the results, including data analysis and result interpretation. Chapter 6 evaluates this research, discussing limitations and offering suggestions for improvement. Chapter 7 presents the conclusions drawn from the experiment and offers recommendations for future work.

Chapter 2

Background

2.1 Project Background

2.1.1 Preference Aggregation

Preference aggregation allows participants to have an influence in the outcome of allocations by allowing them to select preferences [18]. Preference aggregation executes by collecting many individual preferences and applying them to the algorithm, which in best cases would allocate a fair outcome for all individuals [36]. This can be accomplished in different methods called elicitation devices, which each method can allow for users to be more or less expressive with their preferences [50]. When developing preference aggregations you want to make the protocol user friendly, efficient, and the best procedure to express the user's preferences [27].

Ranking preferences is a common preference aggregation, as users can easily determine preferences by ranking best to worst [22]. For a thorough approach, some systems will have users rank all choices, however this can be inefficient for the user with too many choices [35]. Partial rankings will be used to make a preference aggregation efficient for users, however this can lead to losing preference detail, potentially leading to unfair outcomes [25]. Partial rankings is the current preference aggregation being used by the School of Informatics at the University of Edinburgh, allowing students to choose five projects [47].

In scoring, each participant could assign different scores (0-10) to each choice expressing the difference in the preference for each project [39]. Scoring can allow for a user to express more interest in one choice over another, compared to ranking where it is based on the order of choices [66]. Scoring choices have been researched, and this research will classify scoring as not just numbers associated to choices, but as a significant weight added to choices [14]. Scoring offers a different approach compared to ranking by adding weights to each choice, possibly giving users more of an influence over the outcome [61].

Grouping choices into categories can be viewed as a form of broad scoring, where each category represents a score and is described in a way that is more meaningful to the user than a numerical value [24] [63]. This approach is essentially scoring at a more coarse-grained level, allowing users to express general preferences rather than making fine distinctions [11]. In contrast, systems with higher granularity, such as a 10-point scale, require users to make more precise distinctions, which can increase cognitive load and influence overall rating behavior [13]. Grouping is a simple and flexible technique that can be efficient for preference aggregation [57], and unlike ranking methods, it does not require a specific order of choices, which can help reduce decision-making complexity [29]. In large-scale decision-making systems, enabling users to categorize choices into acceptable and unacceptable groups can lead to fairer outcomes [57]. The difference between grouping and finer-grained scoring often lies in the interpretation of the scores, where grouping may involve descriptive categories rather than a numeric scale [11].

2.1.2 Distortion in Social Choice Rules

Social choice theory is defined as the theoretical framework that analyses collective decision-making by aggregating individual preferences [7]. Distortion in social choice measures the discrepancy between the social welfare achieved using an aggregation method with limited information and the best possible welfare that could be achieved with complete information about individual preferences [33]. Specifically, distortion assesses how much the outcome deviates from the optimal welfare, which represents the maximum achievable welfare if complete numerical scores were available [2]. This measure is crucial for evaluating the efficiency and fairness of an algorithm, as it indicates how well the method approximates the best possible outcome given the limitations of the elicited preferences [51]. High distortion suggests that the allocation significantly deviates from the optimal, while low distortion indicates that the method closely approximates the best achievable welfare with the available information [33].

According to Arrow's Impossibility theorem, there is no method of aggregating individual preferences to meet all criteria of a fair-voting system: unrestricted domain, non-dictatorship, Pareto efficiency, independence of irrelevant alternatives, and transitivity[7]. Based on this theorem, this implies that all aggregation systems will have some distortion, as it is impossible to satisfy all criteria simultaneously [56]. The best aggregation of individual preferences will meet as much of the fair-voting criteria as possible, as this ensures that the outcome will be fairer [45]. Every preference aggregation has the potential to be vulnerable to the spoiler effect if it does not follow the criteria listed in Arrow's Impossibility theorem [7]. However, there has been a lot of research determining that the ranking-rule out performs the plurality-rule (scoring choices) by having less impact from the spoiler effect [44].

To mitigate distortion, this usually entails using different methods of preference aggregation to make the individual preferences have more leverage in the algorithm [2]. This can include hybrid preference aggregation and different ways for an individual to express their interest in a preference, including groups and scores [61]. When mitigating distortion it is important to look at the fair-voting system criteria, and try to maximize the use of each simultaneously in a method. [38]. Working towards mitigating distortion is a complex topic and includes a lot of criteria to satisfy when developing preference aggregations [7].

2.1.3 Integer Linear Programming in Allocation Problems

Integer Linear Programming (ILP), which is a subsection of Integer Programming (IP) is used in allocation systems as they can optimize resources and consider constraints in the implementation [4]. In integer linear programming, the main objective is to formulate an objective function that, based on linear constraints, yields an optimal solution by maximizing or minimizing a value. [60]. A general mathematical definition for Integer Programming in allocation is:

Objective Function:

$$\text{Maximize } f(x_1, \ldots, x_A) = \sum_{\alpha=1}^{A} c_\alpha x_\alpha \tag{2.1}$$

where:

- x_α represents the decision variables, which denote the amount of each resource to be allocated.
- c_α represents the coefficients, which indicate the value or cost associated with each unit of resource x_α.

Constraints:

$$x_\alpha \geq 0 \quad \text{for } \alpha = 1, \ldots, A \tag{2.2}$$

$$\sum_{\alpha=1}^{A} q_{\mu\alpha} x_\alpha \leq m_\mu \quad \text{for } \mu = 1, \ldots, M \tag{2.3}$$

where:

- $q_{\mu\alpha}$ represents the quantity of resource α required to satisfy constraint μ.
- m_μ represents the maximum available quantity for constraint μ.

This formulation used is presented in [23].

The linear constraints provide information for the program to ensure that the solution is within the systems requirements such as limits or demand fulfillment [8]. For allocations integer linear programming is an important tool because the algorithm can be flexible, meaning that it can adhere to multiple objectives and constraints [20][41]. Integer programming has helped organizations become efficient, reduce costs, and enhance service quality by optimizing resource distribution [30].

Preferences can be included in an integer linear program by incorporating the preferences in the objective function and the constraints [40]. Preferences can be weights or coefficients in an objective function in an allocation system [41]. When an individual has a higher preference of a choice over another, the objective function can assign a higher coefficient to that preference, and prioritise that preference for that individual [62]. For example in [17] they clarify that minimizing the objective function is the same as minimizing the sum of preferences given by the individuals. Allocations will use integer linear programming as it has been researched as a method to achieve the best outcome in a mathematical model where the requirements are represented as a linear relationship [15].

2.2 Related Work

Integer Programming and Integer Linear Programming has been used with project allocations due to it's ability to solve complex problems with constraints and handle decision variables [55] [65]. These techniques enable the development of allocation algorithms that efficiently adhere to constraints and optimize resources [9][19] . This style of programming has been used to optimize multi-project scheduling, by balancing project deadlines and resource constraints [49]. More research uses integer programming alongside heuristic methods to increase efficiency in allocation algorithms [31]. [28] continues the research looking for better computational efficiency using integer programming with metaheuristic algorithms. Research into using integer programming with multiple criteria was researched by [54], who proposed the Analytic Hierarchy Process (AHP) to handle complex decision-making scenarios. This work illustrates how integer programming is being use in allocation algorithms, and how continued research is looking at increasing computational efficiency.

Preference aggregation is important in decision-making systems, and Arrow's Impossibility Theorem is still used in designing fair voting-systems [6]. Since Arrow's Impossibility theorem, research continues on comparing methods to elicit preferences from individuals and determine which one balances fairness and efficiency the best [10] [32]. Ranking methods are commonly used for preference aggregation, however [46] discusses the limitations to ranking methods. [34] discusses the theoretical framework of scoring systems, and how they can offer more insight on preferences from individuals. Another preference method explored is how allowing individuals to put preferences in groups can simplify preference aggregation by eliminating strict rankings and giving a general preference over choices [46]. These examples show some research of preference aggregations and how each will impact the outcome of the allocation algorithm.

2.3 Contribution

This research makes a significant contribution by developing a preference elicitation platform. This platform allows for the efficient collection of preferences from participants, providing a valuable tool for future studies. By utilising this platform, subsequent researchers can save time and resources that would otherwise be spent on developing similar tools from scratch. Consequently, this platform facilitates the advancement of research by streamlining data collection processes and improving the overall efficiency of future studies.

This research contributes to the field of preference aggregation and project allocation systems. First it evaluates a hybrid preference aggregation method combining ranking with scoring. This method aims to look into the limitations of traditional ranking of projects and explores whether adding scoring component can better capture individual preferences. Additionally, this research evaluates two group preference aggregation methods. The first group method focuses on separating projects into four groups, allowing individuals to concentrate on general preferences. The second method involves dividing projects into two groups labeled ”yes” and ”no”.

Social choice and integer linear programming are applied to analyse the effectiveness of various preference aggregation methods in achieving fair and efficient allocation processes. By utilising integer linear programming with different elicitation devices, this study identifies which methods best align with fairness criteria from [7] and result in lower total distortion. The research also examines the allocation process used by the School of Informatics at the University of Edinburgh [47], and proposes a tailored protocol for their allocation algorithm. The proposed protocol is designed to improve efficiency and fairness for students at the School of Informatics. Overall, this research contributes to the ongoing study of preference aggregation and allocation processes, aiming to enhance efficiency and fairness in these systems.

2.4 Research Context

This research focuses on the University of Edinburgh’s School of Informatics project allocation system, which currently relies on students ranking projects 1 to 5, with projects proposed by both supervisors and students [47]. To be considered for a project, students must be deemed suitable or not suitable by supervisors. The limitations of ranking of partial projects have been noted in previous studies [25], highlighting the need to explore alternative preference aggregation methods. Feedback from many students, referenced in Appendices F and G, have revealed dissatisfaction with the allocation outcome, with some students searching for new projects independently. Additionally, most students indicated that the process of selecting projects to rank is inefficient and distracts from their coursework. While set within the context of the School of Informatics at the University of Edinburgh, this research aims to contribute to broader studies on preference aggregation and project allocation systems, with a focus on ensuring efficiency and fairness. The anticipated findings could inform best practices in preference aggregation and aid in the development of more effective allocation systems.

Chapter 3

Methodology

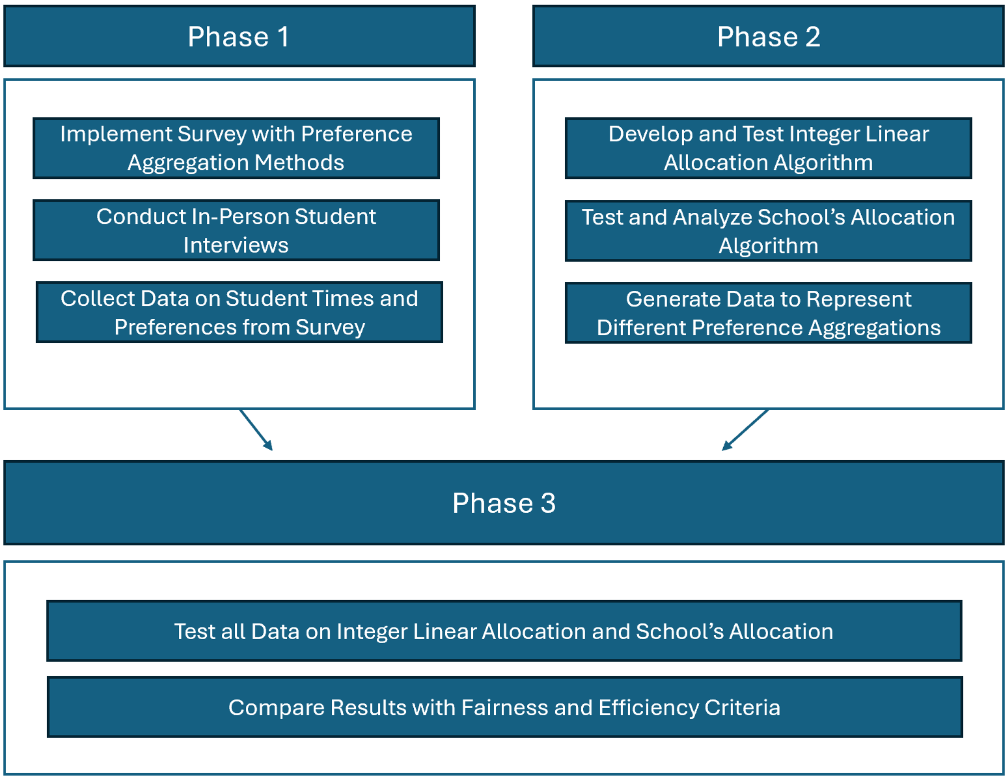


Figure 3.1: Methodology Overview

3.1 Research Design

This research utilises a mixed-methods approach, integrating qualitative and quantitative analyses to improve the allocation process used by the School of Informatics at the

University of Edinburgh. By combining qualitative data from student interviews with quantitative data from an online preference aggregation survey and past allocation data from the School of informatics, this research provides a comprehensive understanding of preference aggregation and it's effect on the allocated outcomes. The research was structured into three phases, illustrated by Figure 3.1.

Phase 1 involved the design and implementation of the survey, along with the collection of student experiences through interviews. Phase 2 focused on the implementation of an Integer Linear Program (ILP) to test and analyse the existing allocation algorithm used by the school. This phase also included the generation of data that represented various student project preferences under different preference aggregation protocols. Phase 3 entailed the analysis of data collected in the previous phases, where efficiency and fairness criteria was applied to assess the results.

This approach aimed to develop a user interface capable of collecting data through a series of tasks completed by students with the different proposed preference aggregation protocols. This data also included their feedback on their preferred protocol. Student interviews were conducted to obtain feedback from current students about their experience with the current allocation algorithm at the School of Informatics at the University of Edinburgh.

The implementation of the Integer Linear Program with data analysis, was a quantitative approach which allowed for the data from the School of Informatics to be analysed along with generated data for the new preference aggregation methods. By using the school's allocation algorithm and the developed integer linear allocation program, both datasets were processed, allowing for a comparison of outcomes based on principle from social choice theory.

3.2 Conceptual Design

3.2.1 Fairness and Efficiency Criteria

This research is established in the implementation of different preference aggregation methods and assessing their fairness and efficiency using principles from social choice theory. The principles were proposed by Arrow's Impossibility Theorem: unrestricted domain, Pareto efficiency, independence of irrelevant alternatives, and transitivity [7]. The other principle being used is truthfulness which is part of mechanism design stated in [12].

To evaluate these principles, this study adhered to the guidelines set by Arrow's Impossibility Theorem:

- Unrestricted Domain: The protocols were tested with various sets of preferences, including unusual and extreme cases, to ensure they accommodated any possible preference orderings [43].
- Pareto Efficiency: The algorithm used was a maximization objective, which means that the algorithm developed in this study should satisfy this [1].
- Independence of Irrelevant Alternatives: The protocol outcomes were evaluated to determine whether adding or removing irrelevant alternatives affected the relative preferences of individuals [37].
- Transitivity: The protocol outcomes will be analysed to ensure that the individual preferences resulted in consistent and logical outcomes [59].
- Truthfulness: Based on participants and previous student data, it is hard to demonstrate that all data is truthful and there is no one "gaming" the system. This was noted in one of the survey responses in Appendix G, that some people tried to "game" the system to receive their top choice. Unfortunately that means this will most likely fail in this research.

In addition to these principles, the study will also assess fairness by analysing the outcome from the allocation methods and calculating the distribution, approximation ratio, and the distortion [2]. The efficiency is measured by the time it took students to complete each preference aggregation protocol on the survey.

3.2.2 Preference Aggregation Methods

This research focused on four preference aggregation methods. The first method involved partial rankings, which is the method currently in use by the University of Edinburgh [47]. Presently, students at the University of Edinburgh, sort through hundreds of projects and rank 5 projects 1 to 5. This method replicated the current preference aggregation used at the School of Informatics, but participants were asked to rank 20 projects 1 to 20. This method was utilised to collect data on efficiency and to serve as a benchmark for comparison with the other methods. Reference to this method further in this research is ranking.

The second method was a hybrid preference aggregation approach that incorporated the previous 20 ranked projects. In this method, participants were required to assign a score from 0 to 10 to each ranked project. The hybrid model imposed a constraint: participants could not assign a higher score to a lower-ranked project compared to a higher-ranked project. The purpose of this hybrid model was to determine whether creating a weight based on both rank and score would improve fairness and efficiency compared to ranking alone. The hybrid model should allow individuals to have more of an influence because of the added score feature, compared to ranking alone according to [66]. Reference to this method further in this research is scoring.

The third method involved asking participants to group 20 new random projects from the database into 4 categories: ”I want this project”, ”I am okay with this project”, ”I don’t want this project”, and ”I am not qualified for this project”. This method was designed to give participants greater flexibility in expressing their general preferences, with no limit on the number of projects that could be placed in each category. Reference to this method further in this research is grouping.

The final method required participants to group projects into two categories ”yes” and ”no”. This method involved a new set of 20 random projects from the database, and participants were asked to indicate their preferences by selecting yes or no for each project. The purpose of this method was to provide participants with a simple approach to expressing their general preferences over projects. Reference to this method further in this research is approval.

3.3 Data Collection Methods

3.3.1 Online Survey

The online survey was developed as a webpage-based application, because there was a need for more user interaction with the preferences, and this was not capable using a standard online survey tool. In the online survey, participants were presented with 20 random projects on each page from a database of 248 projects. Each project was accompanied by it’s name and description. The online survey was distributed to current and former students of the School of Informatics at the University of Edinburgh. The first page of the survey included an ethics consent and information sheet, as shown in Appendix C, where each participant had to agree to proceed with the survey (Appendix D Figure D.1).

The subsequent four pages of the survey presented the different preference aggregation methods. These included the ranking of projects (Figure 3.2), scoring the ranked projects (Figure 3.3), grouping projects into four categories (Figure 3.4), and approving project options (Figure 3.5).

The ranking page allowed participants to drag and drop projects into the desired order of preference.

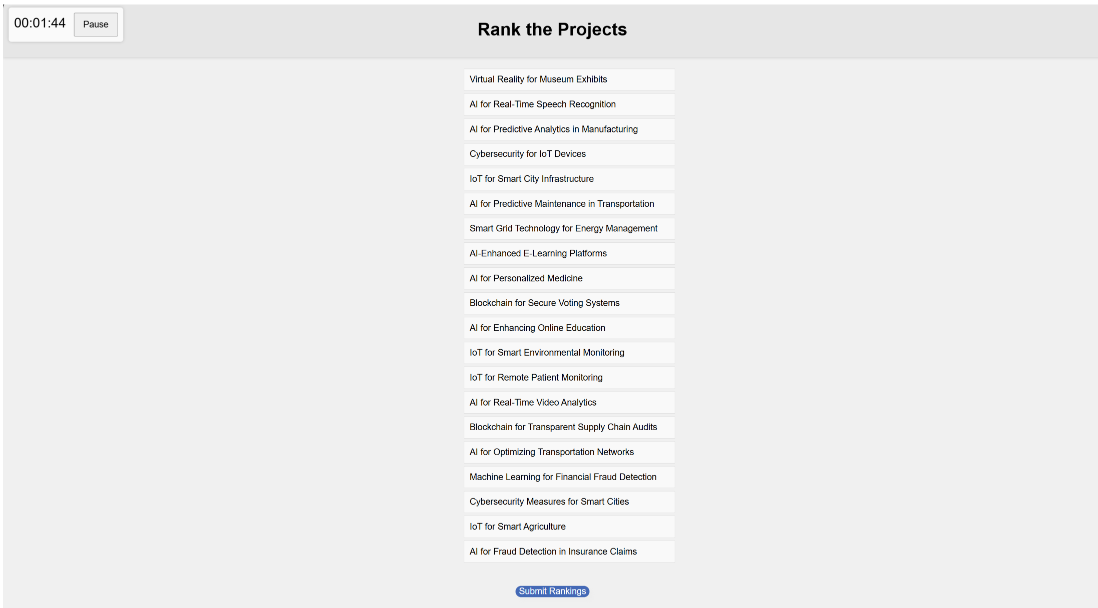


Figure 3.2: Rank Page

The scoring page allowed participants to assign scores (0 to 10) to the previously ranked projects, providing them with more influence beyond simple ranking.

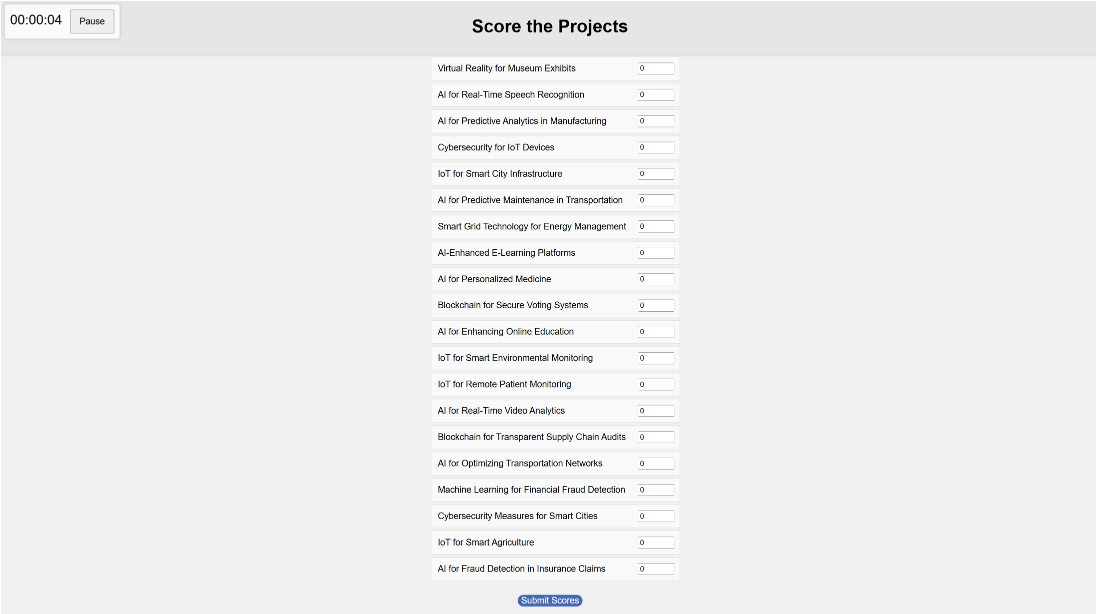


Figure 3.3: Score Page

The grouping page allowed participants to categorize a new set of 20 projects into four groups, allowing for more descriptive general preferences regarding projects.

Figure 3.4: Group Page

The approval page allowed participants to classify the 20 new projects into two groups: ”Yes” or ”No”, enabling a straightforward expression of general preference.

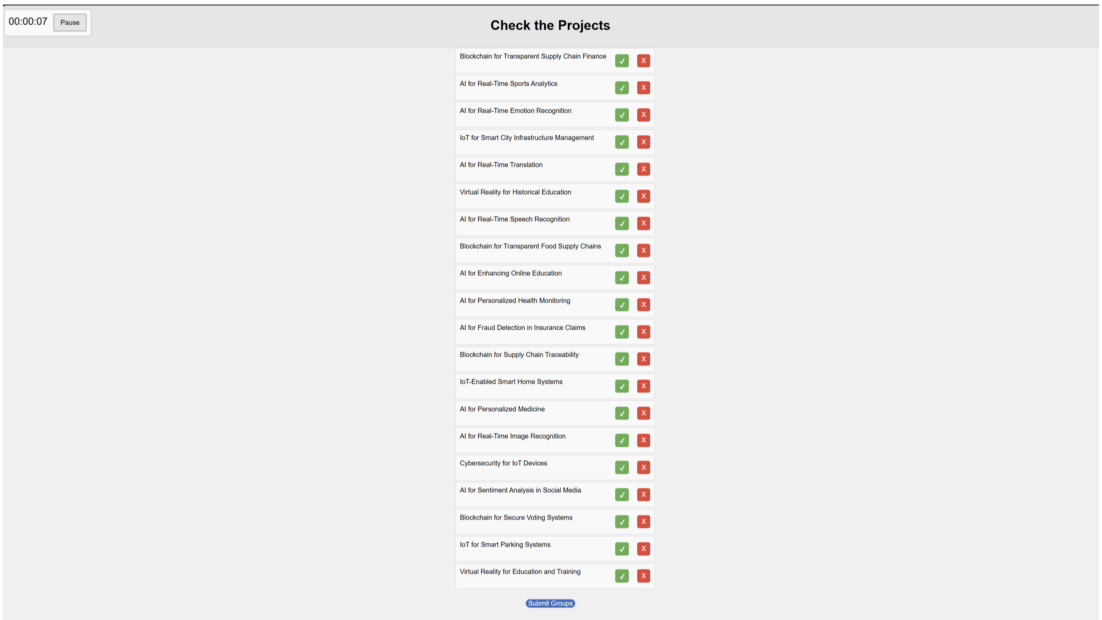


Figure 3.5: Approval Page

At the end of the survey participants were asked which preference aggregation method they preferred, along with other questions regarding their thoughts on the allocation process.

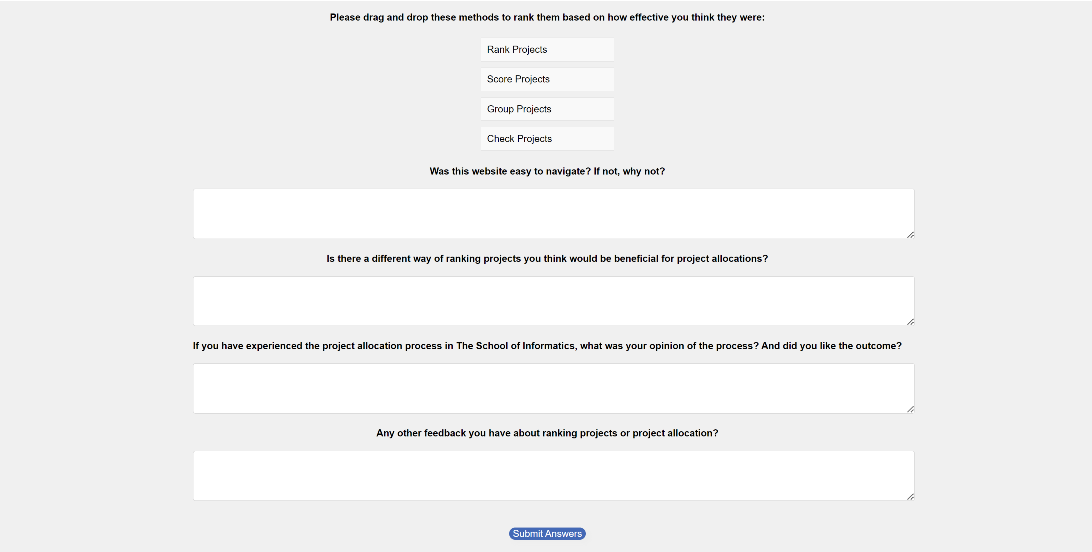


Figure 3.6: Comment Page for the Online Survey

The data collected from the participants included their project preferences under each preference aggregation method, the time taken to complete each method, and their responses to the concluding questions of the survey. The time taken is important for each preference protocol, as this helped determine efficiency of each preference aggregation method in this research.

3.3.2 In-Person Interviews

In-person interviews were conducted to obtain detailed feedback from former students regarding the allocation process. Each student interviewed reviewed the Participants' Information Sheet (Appendix A) and signed a consent form (Appendix B).

The interviews comprised 18 questions, detailed in Appendix E. The structure of the interviews involved participants to first complete the online survey. After they were asked to provide feedback on their likes and dislikes regarding the preference aggregations methods. Participants were then queried about their personal experiences with the project allocation process, and were asked to provide suggestions for improvements to the allocation process.

The objective of the in-person interviews was to gather a diverse range of perspectives of the allocation process, including both positive and negative experiences.

Chapter 4

Implementation

4.1 Phase 1

4.1.1 Online Survey Development

The online survey was developed to facilitate the collection of student project preferences using four preference aggregation methods. The objective was to replicate the approach currently used by the School of Informatics at the University of Edinburgh. Utilising JavaScript and HTML, an online platform was created, allowing for the collection of relevant data from students. The survey was populated with project data from recent years provided by the School of Informatics.

Each survey began with an ethics consent page, to ensure the participants were informed and agreed to participate in the study. Each preference aggregation page displayed 20 randomly selected projects from the project data and a timer, as illustrated in Figure 4.1.

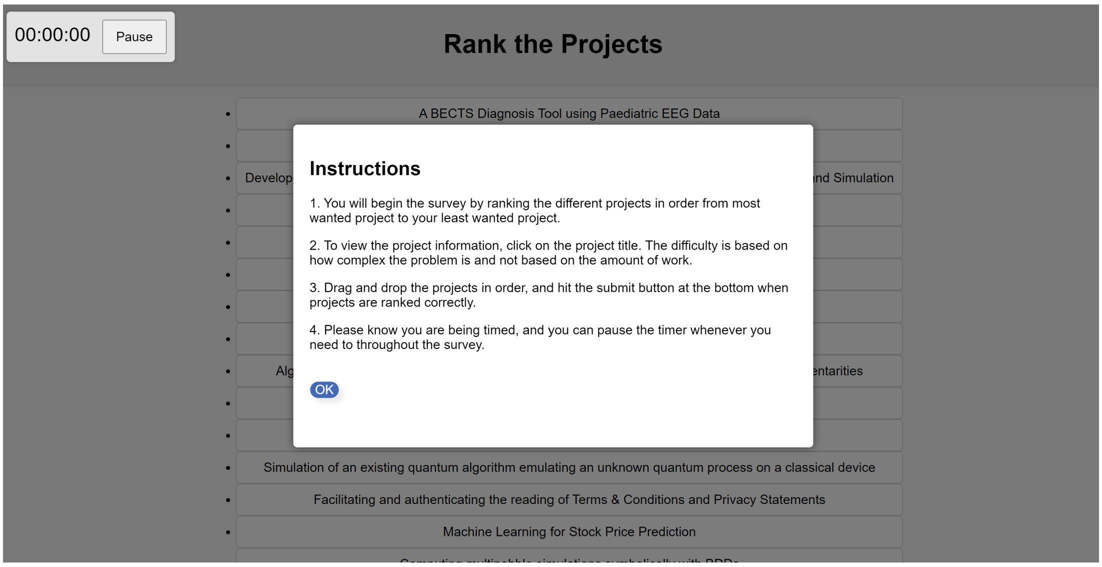


Figure 4.1: Example of Instructions and Survey Set-Up

The survey pages began with instructions for participants, with the timer initiating upon the selection of the ”OK” button. A pause function was included, allowing participants to stop the timer if needed. During the pause, the screen went black and a resume button appeared (Figure 4.2). This feature ensured accurate timing for the completion of each preference aggregation task, preventing participants from reviewing projects while the timer was paused.

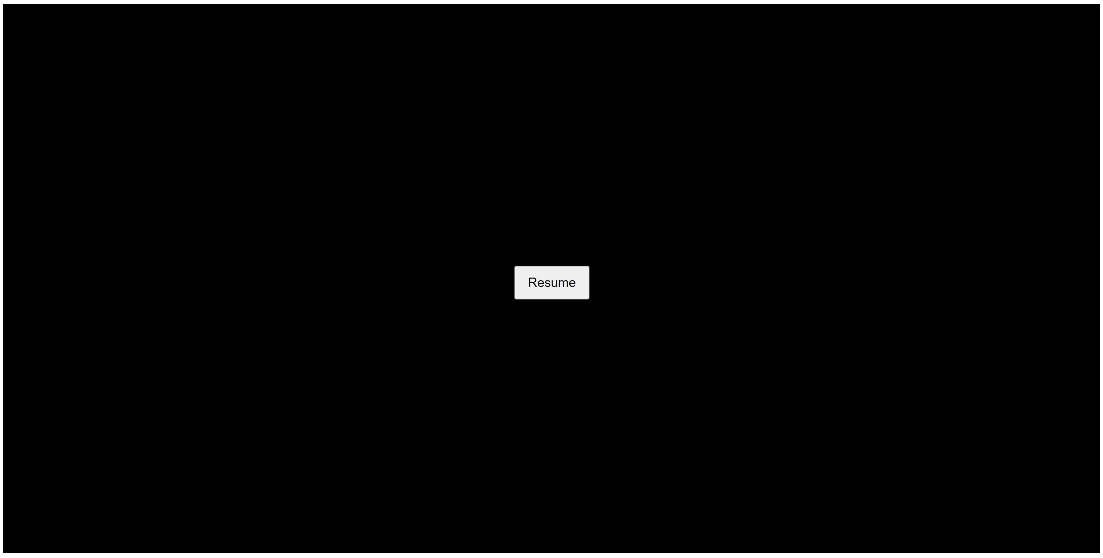


Figure 4.2: Example of Page Being Paused

Each project listing included the name of the project, and participants could click on the project title to view a detailed description in a pop-up window. Based on the information the participants were able to determine their preferences.

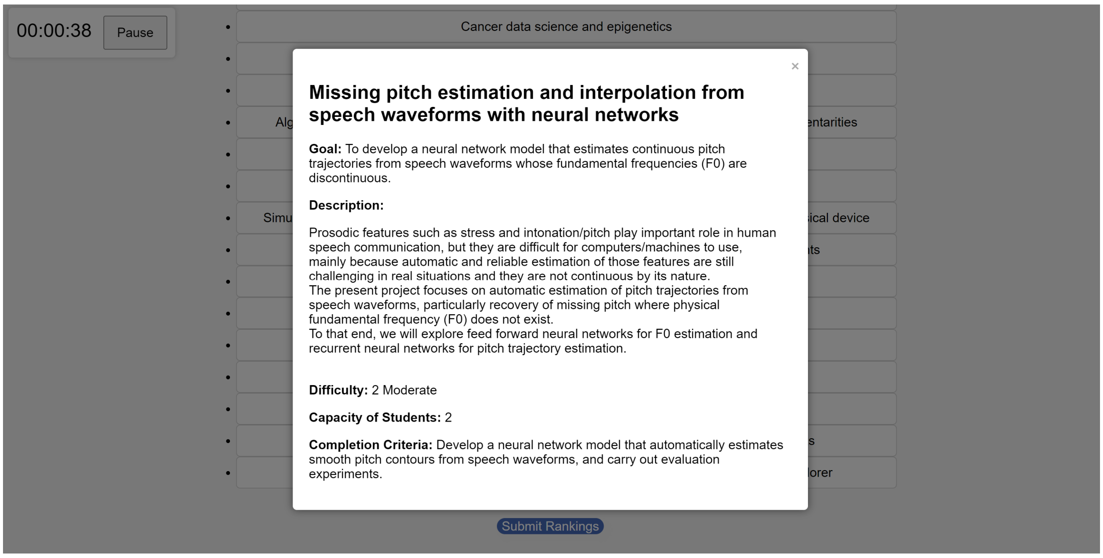


Figure 4.3: Example of Project Details Shown

The survey consisted of four pages, each one corresponding to the preference aggregation protocols. Upon submission of each page, the timer's value and the array of project preferences were stored in the browser's local storage. Default settings were established to handle incomplete submissions:

- Ranking - projects were stored in their original order.
- Scoring - projects were assigned a score of zero.
- Grouping - projects were placed in the "I don't want this project" category.
- Approval - projects were marked as "No"

These defaults ensured consistency in the number of projects assessed across all participants.

After completing the tasks, participants were presented with a feedback page (Figure 3.6). The first question asked them to rank the preference aggregation methods based on their ease of expressing preferences. The second question gathered feedback on the website's navigability, aiming to identify areas for improvement in the future. The third question asked participants to suggest alternative methods for expressing their preferences, contributing to potential future research. The fourth question sought insights into the participant's experiences with the school's allocation process, assessing whether it meets the student's needs. The final question provided an opportunity for additional feedback on the survey or the allocation process, identifying potential problems or ideas for future research. All input boxes were sanitized to prevent malicious attacks, ensuring the secure collection of relevant participant information. The submit button stored all the responses in an array in the browser's local storage.

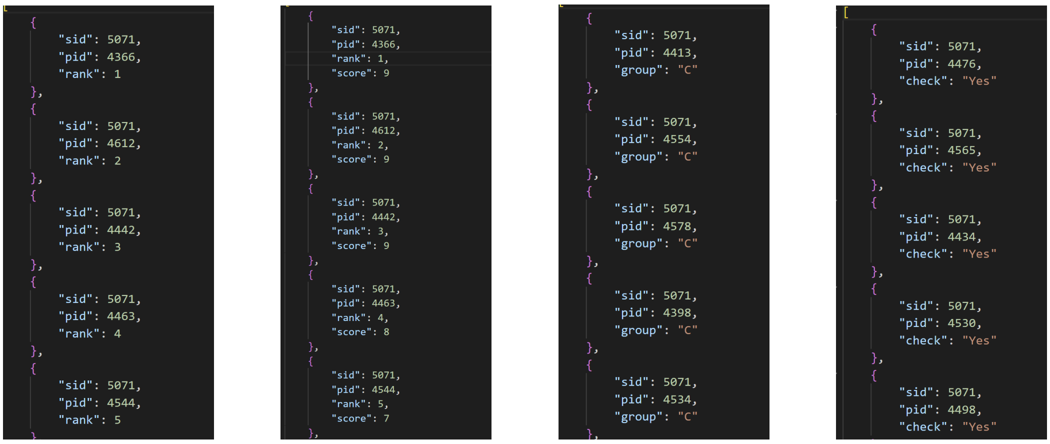
Once the survey was completed, all the data was securely transmitted to a database using Amazon Web Services (AWS). After being sent to the database, all the data was cleared from local storage. Given that the website was being hosted publicly on GitHub, it was essential to ensure a secure data transfer process. AWS allowed this secure connection through the use of an API key and using Cross-Origin Resource Sharing (CORS), restricting access to the database. Comprehensive front-end and back-end testing was conducted on the survey to verify data was processed correctly, and the functionality of the user interface.

4.1.2 Collection of Data

Data collection in Phase 1 involved gathering information from both the Online Survey and in-person interviews. The second component of data collection in Phase 1 was in-person interviews. The in-person interviews provided valuable qualitative data that highlighted potential inefficiencies and fairness issues within the existing system, these are expressed in the result system.

Once participants began completing the online survey, the data was downloaded from the online database and saved as JavaScript Object Notation (JSON) files for each participant. To ensure anonymity, each participant was assigned a random student ID. A python script was developed to process the individual JSON files and compile them into new JSON files categorized by preference method, organizing the project preferences collected from each student.

As shown in Figure 4.4(c), the grouping uses the classifications A, B, C, and D. For testing with the allocation algorithm, these group names were used for simplicity. Group A corresponds to ”I want this project,” Group B to ”I am okay with this project,” Group C to ”I don't want this project,” and Group D to ”I am not qualified for this project”.



((a)) Rank ((b)) Score ((c)) Group ((d)) Approval

Figure 4.4: Input Data Produced From Survey

The process resulted in the creation of four distinct files (Figure 4.4): ranking preferences, scoring preferences, group preferences, and approval preferences. Each file contained data from all participants, listing the 20 project IDs associated with each participant and their corresponding preferences. These JSON files served as the input data for the integer linear allocation algorithm. The data generated through this process was crucial for testing the algorithm and evaluating how different preference aggregation methods impacted the outcomes of project allocation.

4.2 Phase 2

4.2.1 Testing and Analysis of the School's Allocation Algorithm

The school indicated that specific information related to the code and data files of their allocation algorithm could not be disclosed. The school's allocation algorithm was provided for testing purposes, allowing inputs to be tested and outcomes to be generated for analysis. Additionally, allocation data from two previous years (2018-2019 and 2020-2021) was also provided.

Upon reviewing the school's algorithm, it appeared that the constraints considered were:

- Every student was assigned one project.
- No supervisor was allocated more students than their maximum load.
- Projects were not allocated more students than their capacity.

To ensure the algorithm ran correctly, a JSON file was created, which included the students and their project rankings, the supervisors and their maximum load of students, the projects and their maximum capacity. Several Python scripts were executed to process the school data files and produce the correct JSON format required to run the algorithm.

The school's algorithm was tested with this data, and an output was generated. The output included the students, their allocated projects, and the corresponding supervisors. These outputs were crucial for analysis to enable comparison between the outcomes between this allocation algorithm and the one developed in the study.

4.2.2 Development of the Integer Linear Allocation Algorithm

At the beginning of phase 2, extensive research and tutorials on implementing simple integer linear programs (ILP) using Python were conducted. Given the variability of each preference aggregation and the fact that the School of Informatics employed an integer linear program, an integer linear program was implemented for the allocation algorithm using Python and it's associated tools (e.g., pulp) [48] [58].

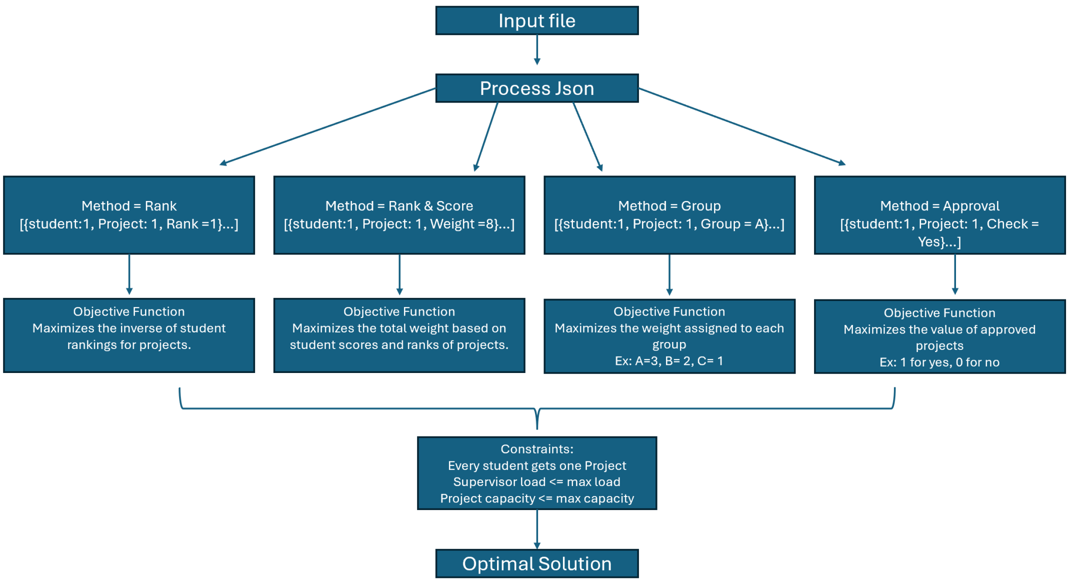


Figure 4.5: Structure Of My Integer Linear Allocation Algorithm

The structure of the allocation program is depcited in Figure 4.5. The allocation program relied on two JSON files: "supervisor.json" and "projects.json", which contained the necessary supervisor and project information for the constraints. The program accepted an input JSON file containing a string of the preference aggregation method name and student project preferences in an array of objects with the student id, project id, and the preference for each project in the format of the specified method. This file was processed by ”ProcessJson.py” where the data was formatted according to the preference aggregation method. Each method formatted the student data appropriately for the given method, which could then be input into the allocation algorithm. For the rank method, it returned an array of sorted values based on the number of rank. For the score method, it returned an array of values sorted by weight, the weight was calculated by combining scores and inverted ranks. For the group method, it returned an array of values sorted by priority, with Group A assigned a priority of 1, Group B as 2, and Group C as 3. Projects in Group D were excluded from the array, as students indicated they were not qualified for those projects and should not be allocated to them. For the approval method, it sorted values with ”yes” projects first with a score of 1, and ”no” projects at the end with a score of 0.

The allocation algorithm then took the input and, based on the method, created the objective function. The objective functions are as follows:

- Rank: Using harmonic scoring the total score is calculated of the student rankings.
- Score: The total weight, which is calculated from the student rankings and scores, is calculated.
- Group: The total weight is calculated from the group weights (e.g., A:3, B:2, C:1).
- Approval: The total value of approved projects (e.g., 1 for yes, 0 for no) is calculated.

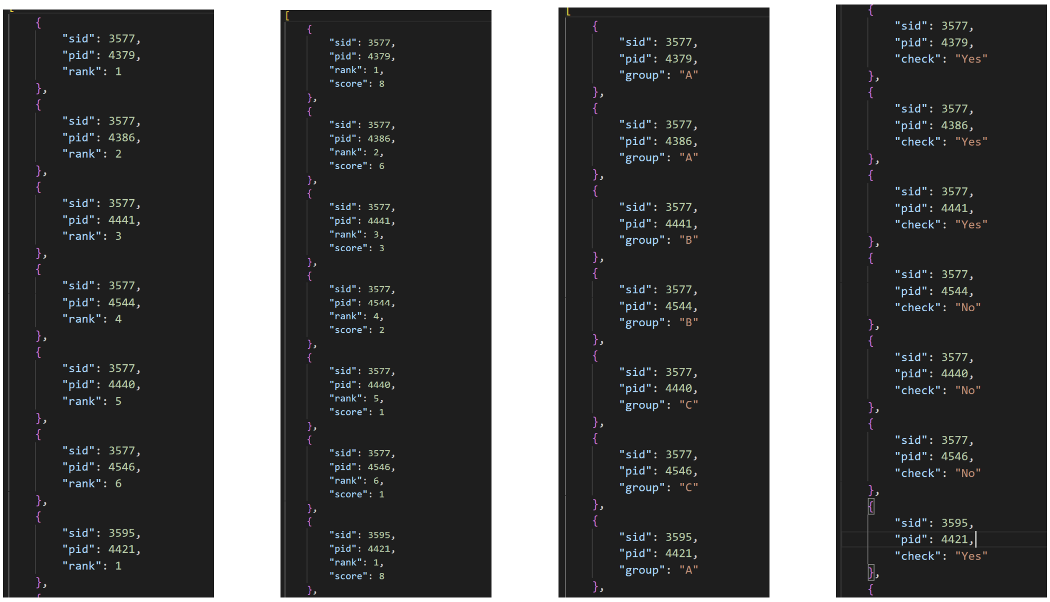
The constraints applied to all methods were:

- Every student was allocated one project.
- No supervisor could have more students than their maximum load.
- No project could have more students than it’s designated capacity.

Based on the objective function and constraints, an optimal solution was found, and students were allocated projects with corresponding supervisors. These results were stored in a JSON file for later processing. Self-proposed projects were not included as a constraint, and were not assessed in the allocation results, as this study did not focus on them.

4.2.3 Data Generation

After implementation of Phase 1, it was determined that there were not enough participants and data generated from the online survey to create input for the allocation algorithm that would produce adequate results for comparison with the school's data. To address this issue, a Python script was developed to generate data for the input of each preference aggregation method based on the ranking data provided by the school. Based on the rank of the projects, the program assigned scores to the projects, grouped them accordingly, and assigned "Yes" or "No" based on the ranks.



((a)) Rank ((b)) Score ((c)) Group ((d)) Approval

Figure 4.6: Generated Data Produced From Ranked Data From School

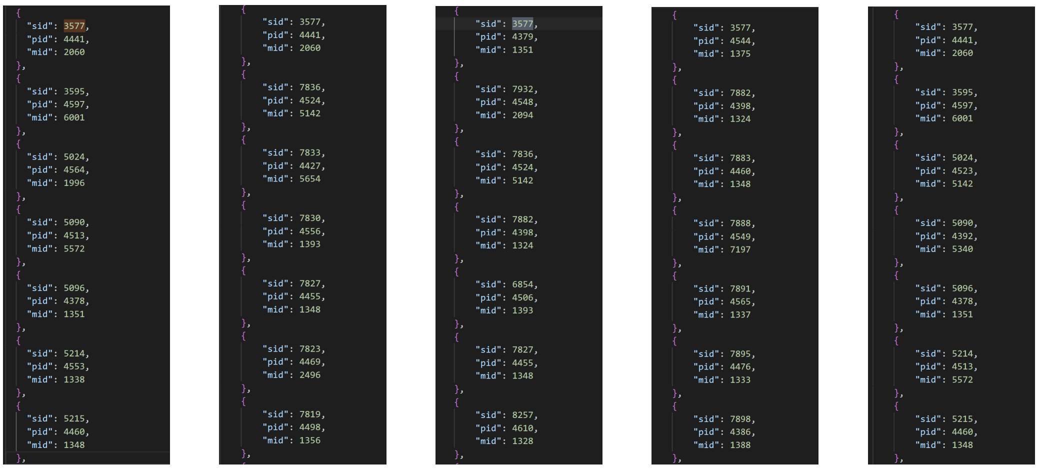
As shown in the example in Figure 4.6, the scoring was based on the rank of the project, with the program assigning a random score from 0-10. A constraint for the score was implemented similarly to how it was handled in the survey: a higher-ranked project received a higher score. For grouping, the top third of projects were placed in group A, the middle third of projects in group B, and the last third in group C. Since these rankings were based on projects selected by students, group D, corresponding to "I am not qualified for this project," was not applied to this data. For approval, the top third of projects were sorted into "Yes," the middle third could be sorted into either "Yes" or "No" with a 70% probability towards "Yes," and the last third were sorted into "No."

This approach allowed the use of real data while testing the school's algorithm, and also enabled the alteration of that data to represent different preference aggregation data for use with the developed allocation algorithm in comparing results.

4.3 Phase 3

4.3.1 Test All Data on Allocation Algorithms

Using all the generated data from Phases 1 and 2, sufficient data was available to begin running the allocation algorithms. For the school algorithm, the ranking JSON files were processed. The developed algorithm was used to run the four different JSON files for each preference method. Each year of data produced five outputs that were saved as output JSON files. For 2018-2019 and 2020-2021 data, the output files included: school rank allocation, rank allocation, scores allocation, group allocation, and approval allocation.



((a)) School Rank ((b)) Rank ((c)) Score ((d)) Group ((e)) Approval

Figure 4.7: Allocated Results From School and ILP Algorithm

As seen in Figure 4.7, the outputs produced variable allocated projects for each student, indicating that the various preference aggregation methods influenced the allocation outcomes. This is described further in results.

4.3.2 Comparing Results

Fairness was evaluated based on Arrow's Impossibility Theorem, allocation distributions, approximation ratio from the ideal and social welfare, and distortion from the optimal and social welfare. For each preference aggregation method, the fairness criteria were analyzed as outlined in section 3.2.1. Five test inputs for each method were created for this analysis:

- Input 1: Different preferences for each individual.
- Input 2: Agreement on some ranks but not all.
- Input 3: Preference for one project over another.
- Input 4: Consistency of project preferences despite the introduction or removal of projects.
- Input 5: Consistency in preference ordering.

The ideal welfare W_{ide} was defined as the sum of the best possible outcomes (top preferences) each student could be allocated without constraints applied:

$$W_{ide} = \sum_{i=1}^{n} R_i$$

[17]

where R_i represented the minimum preference from the preferences of student i.

The social welfare W_{soc} was defined as the sum of the preferences of the projects allocated to the students with the constraints applied:

$$W_{soc} = \sum_{i=1}^{n} R_i$$

[7].

where R_i was the preference of the project that was assigned to student i.

Approximation Ratio, measures the inefficiency of the actual allocation with constraints applied compared to the ideal allocation without constraints applied. This was calculated as the ratio of ideal welfare to social welfare:

$$AR = \frac{W_{ide}}{W_{soc}}$$

[3] [21]

Distortion was calculated from the ratio of the benchmark optimal solution compared to the actual allocation of different preference aggregation methods. In this scenario the benchmark used was the Rank & Score method, as this had the highest optimal solution compared to the other methods.

Chapter 5

Analysis

5.1 Data Analysis

5.1.1 Arrow's Fairness Criteria

Testing was conducted using different JSON inputs along with the supervisor and project data for the year 2020-2021. Various inputs were employed to evaluate the limitations of the protocols, focusing on the principles stated in section 3.2.1. The results for each protocol across the different preference aggregation protocols are summarized in Table 5.1.

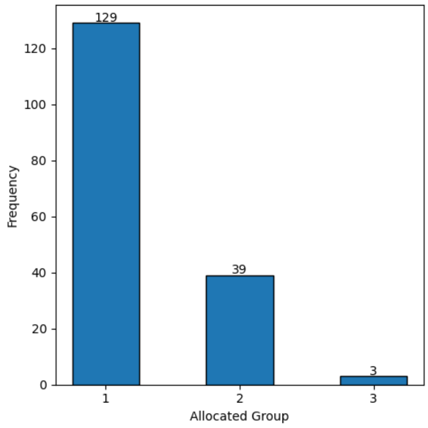
Criteria	Rank	Rank & Score	Group	Approval
Unrestricted Domain	Pass	Pass	Pass	Pass
Truthfulness	Fail	Fail	Fail	Fail
Pareto Efficiency	Pass	Pass	Pass	Pass
Independence of Irrelevant Alternatives (IIA)	Pass	Pass	Pass	Pass
Transitivity	Pass	Pass	Pass	Fail

Table 5.1: Performance of Preference Aggregation Methods Against Arrow's Fairness Criteria.

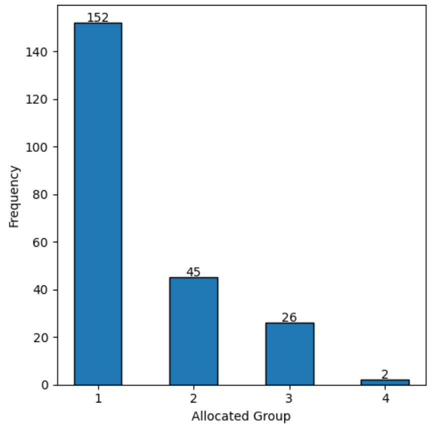
The results indicate the rank, rank & score, and group methods satisfy four out of five key principles of social choice theory, excluding the principle of Truthfulness. This suggests that these methods offer significant improvements in robustness, efficiency, and fairness of outcomes compared to the approval method. All protocols exhibit vulnerabilities in truthfulness, highlighting a common limitation across methods where strategic manipulation can occur.

5.1.2 Distribution of Allocated Projects and Distortion

The graphs illustrate the distribution of projects allocated to students based on their preference for the project allocated, comparing different allocation methods across two academic years: 2018-2019 and 2020-2021.

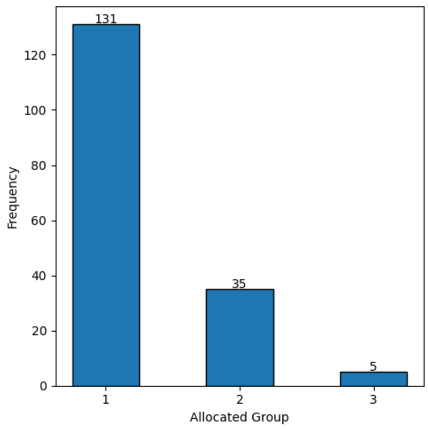


((a)) School Distribution 2018-2019

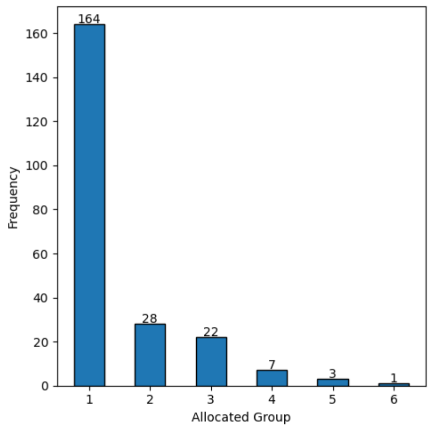


((b)) School Distribution 2020-2021

Figure 5.1: School Distribution of Allocated Ranks

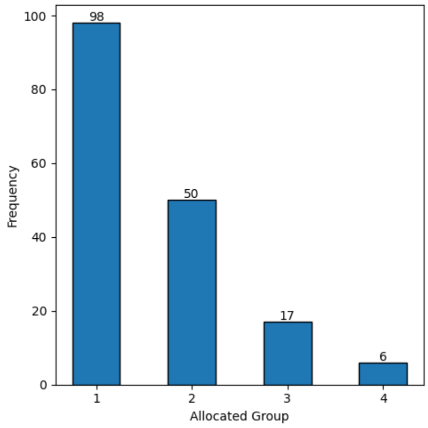


((a)) Rank Distribution 2018-2019

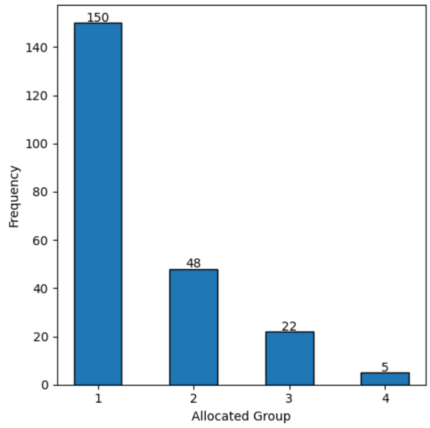


((b)) Rank Distribution 2020-2021

Figure 5.2: Developed ILP Distribution of Allocated Ranks



((a)) Score Distribution 2018-2019



((b)) Score Distribution 2020-2021

Figure 5.3: Developed ILP Distribution of Allocated Ranks Using Score Method

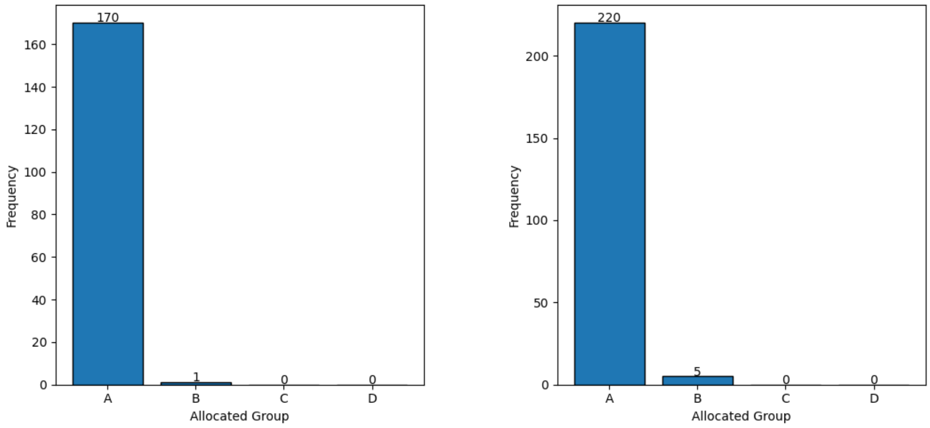
These graphs show that each allocation method prioritises students' top-ranked projects.

	1st Choice	3rd choice	5th Choice
Rank By School	71.5%	6.66%	0%
Rank By ILP	74.75%	6.35%	0.67%
Score By ILP	61.99%	9.86	0%

Table 5.2: Average Distribution Between the Two Years

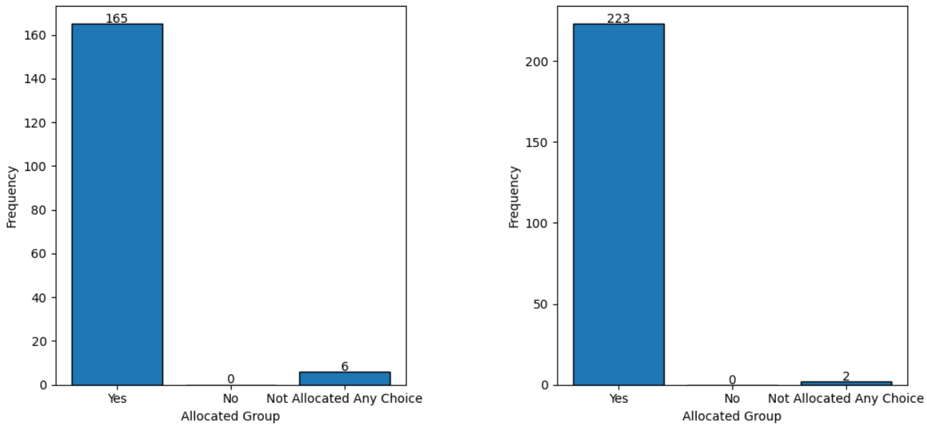
From the table, observations can be made about the allocation. All methods generally allocate a high percentage of projects to students' top-ranked choices. This indicates that all methods prioritise students' first choices effectively. The rank by ILP method performs slightly better in allocating students to their first choice compared to rank by school. The rank & score method tends to distribute choices more broadly, which might indicate more balanced allocations but also potentially less satisfaction for top-choice seekers.

The next graphs are the distributions for group and approval.



((a)) Group Distribution 2018-2019 ((b)) Group Distribution 2020-2021

Figure 5.4: Developed ILP Distribution of Allocated Groups



((a)) Approval Distribution 2018-2019 ((b)) Approval Distribution 2020-2021

Figure 5.5: Developed ILP Distribution of Allocated Approvals

These graphs indicate that both protocols are prioritizing students top preferences. For the group method the majority of students were allocated projects in Group A across both years. On average, 98.6% of students were placed in Group A. This suggests that the group method effectively minimizes highly unfavorable outcomes. The approval method allocated 97.8% of students to approved projects. However, unlike the group method, it included allocations to projects outside the students' preferences. Which suggests highly unfavorable outcomes, which could disappoint a student.

Tests were conducted on the school allocation data from 2018-2019. The following table summarizes the results for the average approximation ratio for each preference aggregation.

	School	Rank	Rank & Score	Group	Approval
Average Approximation Ratio	1.601	1.657	1.017	1.014	1.023

Table 5.3: Average Approximation Ratio of Years 2018-2019 and 2020-2021

Based on this table, the group method achieved the closest performance to the ideal welfare, suggesting that it most effectively allocates students to their top preferences. The rank & score method also performed closely to its ideal welfare, indicating that it similarly succeeds in aligning allocations with students' top preferences.

To align with current practices in the School of Informatics, where students provide only five preferences, the data was adjusted accordingly. These results are summarized in Table 5.4.

	School	Rank	Rank & Score	Group	Approval
Average Approximation Ratio	1.553	1.598	1.065	1.075	1.085

Table 5.4: Average Approximation Ratio For 5 Rankings of Years 2018-2019 and 2020-2021

Based on this table we can see that the school rank and rank performed better, however they were still the worst performing methods compared to the other three. Rank & score achieved the best performance among the methods tested. This indicates that reducing ranks to five does improve rank allocation, but not enough to perform better than rank & score, group, and approval, while the other methods perform worse.

This table shows the average distortion of rank, group, and approval compared to score & rank. Using score & rank as the benchmark as this had the highest optimal value in the allocation process.

	Ranking	Group	Approval
Average Distortion	1.22	17.03	52.27

Table 5.5: Average Distortion Using Rank & Score as the Benchmark Calculation

Based on this table we can see that rank has less distortion than group and approval. This is no surprise as rank and rank & score have more information obtained from the student. However it is important to note the difference between the group and approval distortion values. This suggests that group might have a more fair and efficient outcome compared to approval. There will need to be further investigations into the distortion of each method, as these results show promising evidence.

5.1.3 Survey and Interview Results

Table 5.6 presents the average time it took for the 16 participants to complete each preference aggregation on the online survey. The green cell highlights the method which many participants took less time on, indicating an efficient preference aggregation. In contrast, the red cell marks the method with the longest average time determining a least efficient preference aggregation.

Although the rank & score method took less time for participants to complete, it was a hybrid method that included ranking projects, which reduced it's efficiency compared to the group and approval methods. However, it is worth noting that participants took significantly less time to come up with scores to associate with ranks. This is contradicting to the argument that scoring takes more cognitive load than ranking [3]. This exhibits that adding scores to a ranking process may not substantially increase the time or cognitive effort.

	Ran	Rank & Score	Group	Approval
Average Time	27m 1s	1m 34.7s	4m 14s	2m 26s

Table 5.6: Average Time It Took Students To Perform Preference Aggregation Methods on Survey

It is not a surprise that grouping and approval took less time than ranking and rank & scoring, however it is worth noting the difference in the time it took. On average group and approval took less than five minutes, while rank and rank & score took closer to thirty minutes total. These results align with student preferences for methods perceived as less time-consuming and requiring less cognitive effort.

Feedback from students who participated in the survey indicates that the current preference aggregation method may not effectively represent individual preferences

(Appendix G). According to in person interviews (Appendix F) and the responses from the online survey (Appendix G), many students preferred the group and approval methods, finding them easier for deciding project placements. These methods were perceived as less time-consuming and requiring less cognitive effort compared to rank and rank & score methods.

Student interviews revealed several issues, including challenges with self-proposed topics, difficulties for students who were assigned their least preferred projects, and a lack of support from the school in finding alternative solutions for those dissatisfied with their allocations. Two students who were not allocated their self-proposed projects and decided to change their projects reported receiving no assistance from the school, with the staff showing limited knowledge of the allocation process. All students interviewed expressed that the process was time-consuming, distracted them from their course work, and found the process stressful. Many suggested that the process needs to be reevaluated and potentially revised to better serve the students.

5.2 Results Interpretation

The analysis reveals that the school's current algorithm performs well in terms of distortion and distribution. However, the findings suggest that there is room for improvement in the process to ensure a fairer and more efficient outcome.

The evidence indicates that the rank & score method could be beneficial for students. This method allows students to provide more detailed information about their preferences, resulting in good approximation ratio and a high optimal value. However, the distribution graph shows that fewer students are allocated their top-ranked projects, and the method is not the most efficient in terms of time, as it took students a significant amount of time to complete. Despite this, the minimal additional time required to assign scores alongside rankings, suggests that incorporating scores into a ranking method would not drastically affect the overall efficiency.

Another promising protocol is the group method. Although it has a higher distortion compared to ranking, other evidence suggests that it could be efficient and fair. The distribution graph shows that most students were allocated a project in Group A, with the remaining students allocated a project in Group B, indicating all students received a project they were interested in. This is significant because students generally prefer to be assigned to a project they find appealing rather than one they don't. Furthermore, the group method had the best performance in terms of approximating the ideal welfare of the allocation. It also required less time for students to complete on average compared to rank and rank & score, suggesting that it imposes less cognitive stress and is a more efficient protocol. These findings indicate that further research into using groups as a preference collection method could yield a fairer and more efficient allocation process.

The rank & score and group methods show promising results in allocating projects that align with students' interests. However, when the number of preferences was reduced to five projects per student, these methods did not perform as well. This suggests that allowing students to rank a larger number of projects leads to better outcomes with these methods. Therefore, more research should focus on these methods to improve fairness and efficiency.

Chapter 6

Evaluation

6.1 Implications for Theory and Practice

This research builds upon the theory by [57] that general preferences can lead to fairer and more efficient outcomes for individuals. The results do align with the theory from [57] that approving choices can lead to fair outcomes; however, when compared to groups, it does not perform as well. These results align with the claim by [25] that partial rankings can result in unfair outcomes, and adds to the discussions in [34] that scoring can offer more insight on preferences. It contributes a new idea that scoring may not take as much time when it is performed after ranking, when scoring is thought to require more cognitive effort [3]. Comparing results has added more evidence toward the discussion from [46] that there are limitations to ranking preferences.

These findings contribute to the development of more equitable and efficient outcomes when utilising preference aggregation methods, providing valuable insights for future research and developers. Such advancements could lead institutions and organizations to reconsider how they collect individual preferences, potentially increasing overall satisfaction. The evidence presented in this research should prompt the School of Informatics at the University of Edinburgh to reexamine it's preference aggregation and explore opportunities for improving efficiency and fairness.

Given these results, it is recommended that organizations and institutions investigate various preference aggregation methods. Continued research is needed for hybrid and general preferences, as these have demonstrated superior performance compared to rank and approval. As ongoing research continues to employ social choice theory in analysing allocation algorithms, there is a need for more guidance on how institutions can develop more effective and fair systems. Further research should focus on analysing grouping preference aggregation methods. To ensure fairer outcomes for a broader range of individuals, prioritizing general preferences over ranking preferences appears to be the most effective approach.

6.2 Effectiveness and Limitations

This research addressed two important questions: Which preference aggregation protocols allow for efficient and fair outcomes? And secondly, how can the School of Informatics improve it's allocation process? The study successfully produced promising results for each of these questions. Rank & score and group should be analysed further to support these results. This conclusion was supported by evidence related to distortion, the distribution of allocated projects, and the average times to complete methods observed in the online survey. Regarding the second question, it is plausible that the School of Informatics could improve it's allocation system by adopting a different preference aggregation protocol-one that is more efficient for students and better reflects individual preferences.

However, this study had some limitations. The online survey yielded only 16 responses, which was insufficient to produce a robust data set. Additionally, the projects used in the online survey were drawn from a large sample, resulting in limited overlap with student preferences. This made the survey results challenging to utilise for data analysis. Another limitation was restricted access to the school's data. Only two years of allocation data, which was not from recent years, making it difficult to identify patterns in the allocation process. Furthermore, there were limitations in the calculation of distortion and the constraints used in the development of the integer linear program, which requires further investigation to ensure more accurate and meaningful results.

6.3 Suggestions for Improvement

For future studies, it is recommended that the survey includes general projects for all participants to ensure sufficient data for comparing student preferences. These projects should remain consistent across all preference aggregation protocols to allow for accurate comparisons throughout the allocation process. Additionally, obtaining more school allocation data would be beneficial, particularly to examine how ranking fewer projects has affected student outcomes in recent years. The two years of data used in this research involved students ranking a large number of projects with variable numbers of rankings.

To build on these findings, further research should explore the use of grouping projects with a larger participant pool. Conducting experiments with real data, rather than generated group data based on ranking data provided by the school, could provide stronger evidence supporting the focus on individual preferences through general preferences. Moreover, additional research should be conducted on hybrid preference aggregation systems, as ranking and scoring showed better performance compared to ranking alone. Hybrid preference models may offer a way to incorporate more individual input into general preferences.

This study briefly addresses distortion associated with each preference aggregation method. However, there are limitations as mentioned above which need to be explored further. The distortion method which is useful may not fully capture all aspects of fairness and efficiency in the allocation process. Therefore, further research should aim to refine these calculations and add additional metrics. This could involve examining how distortion interacts with other fairness and efficiency properties. More principles could be considered in the evaluation. For example, incorporating additional measures related to fairness, Pareto efficiency of feasible outcomes, and stability could provide a more robust conclusion. Addressing this limitation will be crucial for developing a better understanding of the effectiveness of preference aggregation methods on allocation systems.

While integer linear programming (ILP) has shown promise, there can be more constraints added to make the outcomes better than what was implemented in this research. Future studies should consider comparing ILPs with solutions from social choice theory, such as stable matching algorithms and other allocation methods with good properties. This comparison could provide a more comprehensive understanding of the strengths and limitations of various approaches.

Chapter 7

Conclusions

7.1 Summary of Results

Evidence from social choice theory and efficiency metrics suggests that grouping projects might be a particularly effective method for representing individual preferences, as it tends to result in a higher percentage of students receiving their preferred projects. Additionally, the rank & score method also proves effective and aligns closely with the current approach used by the School of Informatics. However, incorporating a grouping method could potentially enhance the alignment of allocated projects with student preferences, thereby improving the efficiency of the preference selection process and increasing the likelihood that students are assigned to projects they find most appealing. Given these promising results, it may be worthwhile for the School of Informatics at the University of Edinburgh, as well as other institutions, to explore further research into these methods to refine and potentially enhance their allocation systems.

7.2 Contributions to the Field

This research provides new evidence that grouping preferences into categories significantly influences the outcomes in favor of individual preferences. Additionally, it supports the idea that this method is efficient, requiring less time than ranking preferences. Many student interviews reinforce this finding, with several students noting the ease of using general preferences, as it aids in selecting between multiple projects of interest. This approach offers the allocation process multiple options to assign to students, thereby increasing student satisfaction.

This research also demonstrates that hybrid protocols better capture individual preferences than ranking alone. It further shows that partial rankings and scoring, can skew outcomes and lead to unfair results. By examining two grouping preference aggregation protocols, the study was able to identify the more effective approach to grouping preferences. In this scenario, individual preferences were better respected by allowing users to create multiple groups rather than simply making binary choices.

7.3 Future Work

According to interviews conducted in person, individuals reported that they were not allocated to their self-proposed projects. When analysing the 2020-2021 data using the school's algorithm, all self-proposals ere allocated to the correct students. However, the students who reported not receiving their self-proposed projects were allocated after the year 2020-2021 academic year. This suggests a need to examine data from later years and conduct further research into the allocation of self-proposed projects.

Currently, supervisors have little input in the allocation process. Future research could explore the potential benefits of incorporating supervisor preferences in the allocation method, which may lead to more favorable outcomes for both students and supervisors. This could include researching using two-way matching algorithms to see the improvement on the allocation results.

Multiple survey participants suggested experimenting with different combinations of elicitation methods. Specifically analysing how grouping and ranking methods work together was proposed, which could potentially offer students greater influence in the allocation process based on the results from this research.

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Appendix A

Participants' Information Sheet for Interviews

Project title: How Good is the Project Assignment? The Effect of Preference Information on the Quality of Assignment Outcomes.
Principal investigator (PI): Aris Filos-Ratsikas
Researcher: Belle Watt
PI contact details: aris.filos-ratsikas@ed.ac.uk
This study was certified according to the Informatics Research Ethics Process, reference number 205195. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Aris Filos-Ratsikas
Belle Watt

What is the purpose of the study?

This project aims to enhance the project allocation process by integrating social choice theory to better align student and supervisor preferences with available projects. Addressing inefficiencies and fairness, the study will evaluate various preference elicitation methods and advanced algorithms through experiments using both real and synthetic datasets. Outcomes are expected to not only benefit academic settings but also extend to other sectors like healthcare and corporate environments, potentially transforming how entities approach and implement matching systems. This interdisciplinary approach promises to significantly advance the understanding and application of project allocation, ensuring more efficient and fair results.

Why have I been asked to take part?

You are an informatics student, who will/has taken part in the project allocation process.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time before submitting the online interactive survey.

What will happen if I decide to take part?

- Kind of data being collected includes the time it takes for the participant to complete each page of the interactive survey, and how the participant ranks the projects listed on each page.
- No personal information will be collected from the participant.
- This is an interactive survey where participants will rank projects listed in different ways. These ways include ranking projects, scoring projects on scale 0-10, putting projects in categories, and checking the projects participants are interested in.
- Duration of the session is approximately 30 minutes or less.
- No participant audio/video is being recorded.
- This only needs to be completed once per participant.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

No.

What data are you collecting about me?

The data we collect for our research is completely anonymous: We are not collecting any information that could, in our assessment, allow anyone to identify you. Your signed participant consent form will be kept separately from your responses and destroyed. Consent forms and audio recordings will be destroyed by August 23, 2024.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will not be collecting any personal information. With your consent, information can also be used for future research. We are hoping to make this data open for future research.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, [Belle Watt, A.H.Watt@sms.ed.ac.uk]. If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats

To request this document in an alternative format, such as large print or on coloured paper, please contact [Belle Watt, A.H.Watt@sms.ed.ac.uk].

Appendix B

Participants' Consent Form for Interviews

Below is the form that participants signed/consented to before interviews.

Project title: How Good is the Project Assignment? The Effect of Preference Information on the Quality of Assignment Outcomes.
Principal investigator (PI): Aris Filos-Ratsikas
Researcher: Belle Watt
PI contact details: aris.filos-ratsikas@ed.ac.uk
By participating in the study you agree that:
• I have read and understood the Participant Information Sheet for the above study, that I have had the opportunity to ask questions, and that any questions I had were answered to my satisfaction.
• My participation is voluntary, and that I can withdraw at any time without giving a reason. Withdrawing will not affect any of my rights.
• I consent to my anonymised data being used in academic publications and presentations.
• I understand that my anonymised data will be stored for the duration outlined in the Participant Information Sheet.
Please tick yes or no for each of these statements.
1. I agree to being audio recorded.
2. I allow my data to be used in future ethically approved research.
3. I agree to take part in this study.

Appendix C

Participants' Combined Information Sheet and Consent Form for Website

Project title: How Good is the Project Assignment? The Effect of Preference Information on the Quality of Assignment Outcomes.

Principal investigator (PI): Aris Filos-Ratsikas

Researcher: Belle Watt

PI contact details: aris.filos-ratsikas@ed.ac.uk

This study was certified according to the Informatics Research Ethics Process, reference number 205195. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Aris Filos-Ratsikas

Belle Watt

What is the purpose of the study?

This project aims to enhance the project allocation process by integrating social choice theory to better align student and supervisor preferences with available projects. Addressing inefficiencies and fairness, the study will evaluate various preference elicitation methods and advanced algorithms through experiments using both real and synthetic datasets. Outcomes are expected to not only benefit academic settings but also extend to other sectors like healthcare and corporate environments, potentially transforming how entities approach and implement matching systems. This interdisciplinary approach promises to significantly advance the understanding and application of project allocation, ensuring more efficient and fair results.

Why have I been asked to take part?

You are an informatics student, who will/has taken part in the project allocation process.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time before submitting the online interactive survey.

What will happen if I decide to take part?

- Kinds of data being collected includes the time it takes for the participant to complete each page of the interactive survey, and how the participant ranks the projects listed on each page.
- No personal information will be collected from the participant.
- This is an interactive survey where participants will rank projects listed in different ways. These ways include ranking projects, scoring projects on scale 0-10, putting projects in categories, and checking the projects participants are interested in.
- Duration of the session is approximately 30 minutes or less.
- No participant audio/video is being recorded.
- This only needs to be completed once per participant.

Are there any risks associated with taking part? There are no significant risks associated with participation.

Are there any benefits associated with taking part?

No.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will not be collecting any personal information. With your consent, information can also be used for future research. We are hoping to make this data open for future research.

Data protection and confidentiality

Your data will be processed in accordance with Data Protection Law. No personal information will be collected. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researcher/research team: Aris Filos-Ratsikas and Belle Watt. All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. Since data will be collected without personal information, there will be a random id associated with the data collected, it makes it impossible to trace information back to participants after survey completion. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk. For general information about how we use your data, go to: edin.ac/privacy-research

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, [Belle Watt, A.H.Watt@sms.ed.ac.uk]. If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Consent

By proceeding with the study, I agree to all of the following statements:

• I have read and understood the above information.

• I understand that my participation is voluntary, and I can withdraw at any time.

• I consent to my anonymised data being used in academic publications and presentations.

• I allow my data to be used in future ethically approved research.

Appendix D

Website Pages Not Shown

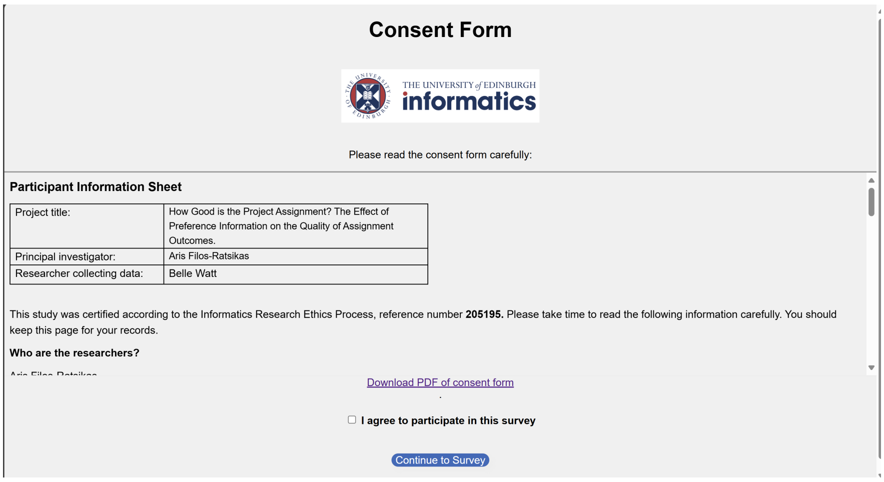

Figure D.1: Consent Form Page.

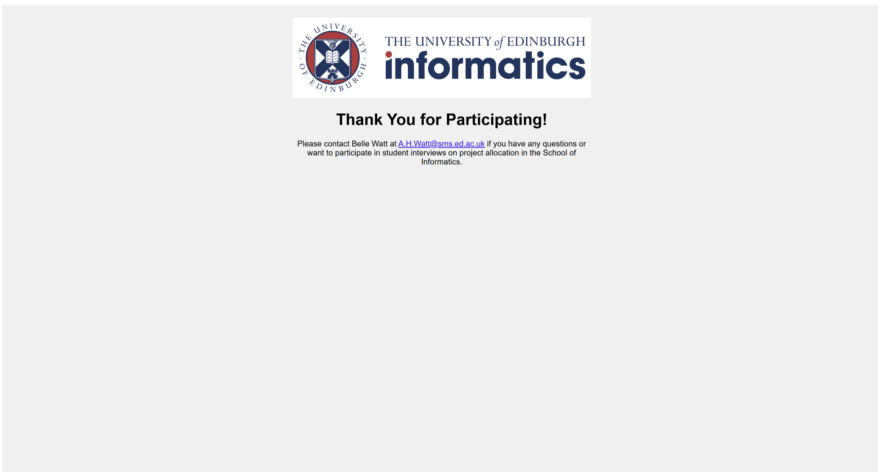

Figure D.2: End of Survey Page.

Appendix E

Interview Questions

- Have them perform the tasks on the Online Survey
- Talk about what they do like about the preference aggregations
- Talk about what they don't like about the preference aggregation
- Any other comments to make about the online survey?
- Have you been through the allocation process in the school of Informatics?
- Did you propose your own project?
- Was the process of selecting projects and supervisors beneficial for you?
- Were you marked suitable, unsuitable, and very suitable by supervisors for your projects? For your selected project?
- How many projects did you rank?
- Which project were you allocated?
- What was your opinion of the overall allocation process?
- Did the allocation process have a negative impact on your academics? Are you motivated to complete your project?
- Any advice on what the school can do to make the process better?
- Did you know enough about the process going into the allocation process?
- Was there anything you wish you knew before the allocation process?

- Do you believe overall the process is fair and efficient?
- If not, how do you think this can improve?
- Any other comments or questions you have?

Appendix F

In-Person Interviews Results

I conducted in person interviews with 4 students from Informatics. Mix of postgraduate students and undergraduate students. These interviews dived deeper into the students experience with the allocation process at the school of Informatics. Each student signed and agreed to a consent form, allowing their information to be used in this report and for future research. Each student number was randomly generated.

- Student 548731: They did not like the process, and it effected their studies at the university. They proposed their own topic and ranked it number 1 and was allocated their 9th choice that they weren't marked suitable for. Said that no one in the school was able to give them a reason why this happened and was not supportive in helping them find a different project. This student felt like no one was investigating the allocation, seeing if it was fair, or if it was working as intended. They stated there was nowhere to make official complaints. They felt like all responsibility was on the student, so it was hard, and they didn't know what to do when they didn't get their proposed topic. They were told the algorithm doesn't make mistakes, which felt like a lack of curiosity from people in an academic institution. This student felt unmotivated to complete their dissertation after finding a new supervisor and new project by themselves, and said it negatively impacted their time at this University.
- The advice that student 548731 gave: publish data on the results of the allocation for students to see, possibly allow students to see the algorithm, have contingencies in place for when a student feels like they have been allocated unfairly, and prepare for those situations. Require the staff to respond to suitable or not suitable and have more clear timelines. Make sure that there are backups for students

ranked unfairly, and make sure a student is not on their own after a bad allocation.

- Student 482739: Proposed their own topic with company support and received that topic in the allocation. They were happy with that result. However they said the process of proposing their topic was poorly laid out, and there was no support. They said the deadline for self-proposing was early and a bad time of the year during the holidays, and it was hard finding a supervisor. There was also no support in finding supervisors. They felt it was a waste of time meeting up with other supervisors and doing a lot of research on other projects, when they were only interested in their project. They thought the process of meeting with supervisors of other projects was a limited timeline and was unnecessary stress during an intense coursework time. They felt like there was no clear deadlines and poor organization and felt like students were not notified of the deadlines until the last second.

- The advice that student 482739 gave: Improve on efficiency: lowering number of project students need to rank, maybe 3 projects. Don't have to approach a lot of supervisors distracting from their work. make the information about the algorithm available to the students. Algorithm is described as a black box, and no one knows how it works, which allows for speculation. So, students don't rank projects based on what they think they'll get instead of what they want. Person in charge needs to give some clear info not speculation to students and set clear deadlines at the beginning of the year. Support and clear instructions for students who want to self-propose. There is no support on how to write a proposal for the DPMT system.

- Student 748923: Did not propose a topic and got ranked their 4th or 5th choice. They wanted to propose their own topic, but there was not enough time to submit one and find supervisor after finding out the deadline of self-proposals. Felt like in the 1-year master's program there was not clear deadlines, and hard to find a supervisor after not knowing a lot of faculty members. They said the process felt rushed and didn't feel fair as they didn't get their interested project. Fingers crossed for top 2 or 3 since they only wanted those. After allocation their supervisor changed the project after their proposal was submitted and during the start of the dissertation time. Project became different than the description, was machine learning and time series data, and turned to probability theory. This caused a big impact; they reached out to their supervisor to approve them to find a new supervisor and they had 2 days to write a new proposal. They said it was really draining and time consuming, took away from their academics and focusing on classes. Process was dragged on, and felt like a waste of time. Not excited to work on their project. Still in touch with other supervisors who wanted to work with them, and they get updated by those supervisors on their projects. More interested in those than their own project.

- The advice that student 748923 gave: Need less time pressure, more guidance in the process, maybe someone to talk to for help in finding a project or a supervisor, and more time for self-proposed projects. Self-proposed felt like a secondary thing and there should be more resources available to help with self-proposals. Need more courage doing self-proposals, there was no support for it. If you self-propose it should be a done deal, not allocated another project. We need more clarification, I didn't know about the difficulty level or what it meant, based it on my own interpretation. Wish we could see the projects first and then could self-propose if we didn't like the projects proposed.

- Student 591204: Did not self-propose and got allocated their 3rd or 4th project, they are motivated and happy with their project. They said the process was quite confusing, lot of speculation how it worked and best to give it a ranking to make it, so you got what you wanted. Hard to know if you should rank projects based on popularity or based on what you wanted. They said it didn't seem efficient, took weeks to find result. Some people they knew didn't get the best project and weren't happy. Wish they knew how you should rank your projects, certain number, if they should take account of popularity. More clear definition of the algorithm and the process.

- The advice that Student 591204 gave: Quicker turnaround of finding out projects or more information why it took weeks, don't know why it's so slow. Have clear guidelines about how students go about the process, clear deadlines at start of term, and make sure staff knows the process as well.

Appendix G

Online-Survey Results

I received 16 survey participants online, where they volunteered to test different elicitation devices and answer questions at the end. Each student agreed to a consent form, allowing their information to be used I this report and for future research. The online survey compromised of the following elicitation devices: ranking projects 1-20, adding a score 1-10 to those ranked projects, grouping projects into categories (I really want the project, I'm okay with the project, I don't want the project, and I am not qualified for the project), and saying yes or no to projects. There was also questions at the end that each volunteer could answer and those are below with the average time it took to complete each elicitation device.

Please rank the following methods based on how effective you think they were:

- ”Group Projects, Rank Projects, Score Projects, Check Projects”
- ”Score Projects, Rank Projects, Group Projects, Check Projects”
- ”Check Projects, Score Projects, Group Projects, Rank Projects”
- ”Check Projects, Score Projects, Group Projects, Rank Projects”
- ”Score Projects, Check Projects, Rank Projects, Group Projects”
- ”Score Projects, Rank Projects, Group Projects, Check Projects”
- ”Group Projects, Score Projects, Rank Projects, Check Projects”
- ”Score Projects, Group Projects, Rank Projects, Check Projects”
- ”Score Projects, Rank Projects, Group Projects, Check Projects”

- ”Rank Projects, Score Projects, Group Projects, Check Projects”
- ”Rank Projects, Group Projects, Score Projects, Check Projects”
- ”Rank Projects, Score Projects, Group Projects, Check Projects
- ”Score Projects, Rank Projects, Check Projects, Group Projects

Is there a different way of ranking projects you think would be beneficial for project allocations?

- ”Grouping, with scoring (or optional ranking) within groups, could better represent my sentiment about the projects. Simple project ranking forces an ordinal ordering on projects that I feel the same about. Grouping allows me to bucket the options more freely without having to place one over another. While simple scoring could achieve this effect, it’s not very user-friendly, because it’s hard to keep track of scores, and often I find myself going back to change the scores on projects I’ve assigned before as I work through the projects list. Grouping allows projects to be progressively categorised as I work through the list, which is helpful. However, simple grouping does not represent well the granularity of sentiment, e.g. “Separate from the project’s I’m okay with, I really want both projects A and B, but want A more than B.”; So, a combination of grouping and scoring could be useful here.”
- ”Maybe a way to filter project based on research group. So, i can focus om what i can work with instead of opening a project that i have no skills for. It’s a waste of time.”
- ”First check them to instantly eliminate ones that the person does not want to do, then rank the ones they want to do, then score them. letting them get rid of a few options at the start makes ranking them easier, then using the score method lets them show if there are any that they equally do don’t want to do. Using a combination of methods would be more efficient than just trying to order the methods from best to worst then picking the best one.”
- ”Unfortunately, we are not made aware in any way of the project allocation algorithm. This makes it almost impossible to decide if there is a better way”
- ”Create some general domain buckets and let students rank projects in those buckets, then rank the buckets themselves. If one project fits in multiple buckets,

you can put it in all of them or just the main one, but this should be clearly communicated, and the project supervisor should be the one to put a project in a bucket. In terms of practically allocating projects, you can allow students to add weights both to buckets and the ranking of the projects. There are many ways of implementing such a weighting system, but any implementation that is chosen should be explained IN DETAIL to the students."

- "I liked the scoring and grouping ones. Ranking was a bit too difficult without numbers associated, for me."
- "probably a mix of all the systems would be useful considering the number of students and projects that are available"

If you have experienced the project allocation process in The School of Informatics, what was your opinion of the process? And did you like the outcome?

- "I experienced a ranking system that considers the top 5 choices and tries to give me my first choice. I received my first choice and was satisfied with the outcome. But I was forced to ordinarily rank projects that I felt the same about, which was a bummer."
- "The system for submitting preferences was fine, however I thought that the process as a whole was unnecessarily mysterious, and often it was impossible to get answers about simple details of what we should do from staff."
- "I had to gamify. I know it wasn't allowed but i had to. And it worked for me. I got the project i wanted. I think the school needs to be more transparent. Ex. At the start they say they don't know what the outcome will be but in the middle before announcement of allocation they said that usually people would get first or second choice. Also, i see that some projects are low in interested students and some have really high interested students, so I'll say that it is gamification either way and that there is a way to get the project I want. As I intentionally only have 1 high interest project ranked number 1 and the second has low interest in students. So, I don't have issues with the algorithm but more like the social part of the process."
- "Thankfully, I have self-proposed a project and thus was given it automatically. For the most part however, most of peers did not get their top 3 choices"

- ”Too secretive on the details. The entire ranking and allocation process was made a black box for no reason and to the detriment of students. Opensource the algorithm and let students simulate things because at the end of the day it is not about what you prefer or you are qualified for, it is about the odds of what you can get. A VPN is required to access the platform unless EDUROAM is used. In fact, the platform itself feels outdated and lacks a lot of quality-of-life features. Direct communication with the supervisor through the platform is one. A better breakdown of the odds of getting the project based on other user preferences and outcome of suitability. And there could be many more. I was happy with the allocation result & outcome but not with the process for the above-mentioned reasons.”
- ”I think the process should be simplified and more transparent. It would be great to know why you weren’t allocated a project you picked as your first.”
- ”I thought the process was ok but took far too long to get the results and having to individually meet with supervisors even for projects that weren’t in my top 3 for example was quite a waste of time.”
- ”It was a bit difficult to sort through the projects given how many there were (not that the variety and number of projects is a bad thing, it just makes searching difficult). It would’ve been quite easy to miss projects which I might’ve found interesting if I didn’t go through them one by one. I was happy with the project I received, but because it was quite a niche area, very few people had applied for the project I got, which (probably) made it a lot more likely for me to get it”
- ”It was a negative experience. Huge impact on my final year of university and wasted a lot of time trying to improve my situation to no avail. No recognition of the impact that was caused to me or assistance to rectify.”

Any other feedback you have about ranking projects or project allocation?

- ”Transparency on information sharing. Sharing the info about project allocation as early as possible like maybe 1st semester so people who want to propose project can do so (especially those who came here by company scholarship) because when given on second semester it is a bit too much. So maybe you can make it into a few parts. Also, i think introducing the research groups and who will be supervising and what their expertise is would be helpful (this is done at Uni of Birmingham). And make a filter that is easier to use and navigate.”

- ”instead of only using the rank method at the end page (for score, rank, group and approval) you should also use the scoring method, as some people may find two of these methods equally good. also, when working with a smaller number of things to rank it makes it seem like there is a big jump in how good each of the methods are as you go down the ranking. the score method would be able to show numerically how close each of the methods are in terms of how good they are.”
- ”Please do a study on the platform used for allocation and ranking. There are many good ideas that would help the project allocation process that do not have anything to do with the ranking system.”
- ”Given the large number of projects available in the real system, I think going one-by-one and giving each a numerical ranking, ordering etc. is too time consuming. Perhaps you can only rank the ones you have expressed interest in to begin with to speed that process up”
- ”someone needs to be responsible for checking the fairness of the algorithm and understanding how it works and checking it every year.”