A Web-based Project Allocation System

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Abstract

This project plan outlines a matching problem between students and projects subject to various constraints. In particular, a web-based system will be implemented to model this problem, together with an algorithm to generate the best matching. Besides, technical aspect of the system is examined. Finally, a tentative schedule is included with distinct milestones to be achieved.

1 Introduction

In many universities, students are generally required to undertake a project before they graduate. Lecturers first propose one or more projects for students to choose from. Students can then take any one of these projects and are supervised by the corresponding lecturers. In addition, different students can work together as a group. Usually, these projects are not expected to be fully taken up by students whilst the number of these are generally sufficient for all students.

1.1 Problem Statement

To reduce the chance of clashing between different students, each student is required to provide a finite number of projects with priority that they are interested in. This is known as the preference list. Likewise, each lecturer is required to provide a preference list on students for each project.

The problem in here is to find the best\(^1\) matching between students and projects. It is similar to that of the Student-Project Allocation Problem (SPA), which can be further generalised by the Two-sided Matching problem [1].

In this project, a web-based system will be developed to stimulate this matching problem. And an algorithm is introduced to solve this problem. Both students and lecturers submit their preference lists on the web-based system and the best matching is returned.

The remainder of this plan proceeds as follows. First, a mathematical description of this problem is introduced together with a current solution. Next, the Project Allocation System is presented with distinct objectives to solve this problem. Then the implementation details are followed. Finally, risks and migrations are discussed and a tentative schedule is included.

\(^1\)Definition will be discussed in Section 2.1.
2 Background

Finding the best matching between students and projects can be done manually when both the size of students and projects are fairly small, possibly within 10. A straightforward approach to construct a matching is individually matched each student to an unallocated project that has a highest priority on the student’s preference list. However, when these numbers become substantial, constructing such a matching manually can take up to few months or even impossible.

Besides, this decentralised approach is known to be deficient and cannot guarantee the stability property [1]. Therefore a software system that able to automatically construct the best matching is desperately needed.

2.1 Theoretical Aspect

Mathematically, the SPA can be described in a following way. Let

\[ S = \{s_1, \ldots, s_n\} \] be the set of \( n \) students,
\[ L = \{l_1, \ldots, l_m\} \] be the set of \( m \) lecturers and
\[ P = \{p_1, \ldots, p_q\} \] be the set of \( q \) projects.

Each lecturer \( l_i \) offers a subset of project \( P_{l_i} \) which is a partition of \( P \). Assume each project is uniquely offered by one lecturer, the disjoint union of \( P_{l_1}, \ldots, P_{l_m} \) is then \( P \). Each student \( s_i \) has a preference list \( \alpha_i \) which contains a ranked subset of \( P \) in a strict order. Similarly, each lecturer \( l_i \) has a preference list \( \beta^j_i \) for each project \( p_j \) in \( P_{l_i} \) (i.e. offered projects) ranked in a strict order. Also, each project \( p_i \) has a capacity constraint \( c_i \) which limits the maximum number of students in this project. Likewise, each lecturer \( l_i \) has a capacity constraint \( d_i \) which limits the maximum number of students that the lecturer can undertake.

It follows that a matching or an assignment \( M \) is a subset of \( S \times P \) such that [1]:

1. If \((s_i, p_j)\) belongs to \( M \), then \( p_j \) belongs to \( \alpha_i \), that is, \( s_i \) preference list contains project \( p_j \);
2. For each student \( s_i \), at most one project \( p_j \) is matched in \( M \);
3. For each project \( p_i \) in \( P \), \(|(s_k, p_i)| \leq c_i \), that is, the number of students matched must not greater than \( c_i \); and
4. For each lecturer $l_i$ in $L$, $|(s_k, p_j)| \leq d_i$ for all $p_j$ in $P_{l_i}$, that is, the number of students matched must not greater than $d_i$.

Then $(s_i, p_j)$ means that $s_i$ is assigned to $p_j$. If $p_j$ is offered by $l_k$ then it also means $l_k$ is assigned to $s_i$.

It follows that the stability of a matching may be defined as follows [2]:

**Definition 1** A matching $M$ is called stable if it does not exist two students $s_1$ with project $p_1$ and $s_2$ with projects $p_2$, that $s_1$ prefers $p_2$ to $p_1$ and $s_2$ prefers $p_1$ to $p_2$.

An example is illustrated as below. Suppose lecturer $l_1$ offers project $p_1$ and that of $l_2$ offers project $p_2$. Student $s_1$ has a preference list of $\alpha_1 = \{p_2, p_1\}$ such that $p_2$ is more preferable than $p_1$. This priority, as defined, applies to preference lists of all students and lecturers.

\[
\begin{align*}
  s_1 &: p_2, [p_1] & l_1 &: s_2, [s_1] \\
  s_2 &: p_1, [p_2] & l_2 &: s_1, [s_2]
\end{align*}
\]

(a) Unstable matching

\[
\begin{align*}
  s_1 &: p_2 & l_1 &: s_2 & s_1 &: p_1 & l_1 &: s_2, s_1 \\
  s_2 &: p_1 & l_2 &: s_1 & s_2 &: p_2 & l_2 &: s_1, s_2
\end{align*}
\]

(b) Stable matching

Figure 1: An example to illustrate (a) Unstable matching and (b) Stable matching, with their assigned project or student boxed.

An *unstable* matching $M'$ happens when $M' = \{(s_1, p_1), (s_2, p_2)\}$ (see Figure 1(a)). When such a pair exists, a *stable* matching $M = \{(s_1, p_2), (s_2, p_1)\}$ (see Figure 1(b)) can always obtain by swapping their projects. This stable matching is better than that of the unstable.

There are potentially many stable matchings existed in a SPA instance. However, among of all these matchings, the *optimal* one is preferred [2]:

**Definition 2** A stable matching is called *optimal* if every student is at least as well off in this matching as in any other stable matchings.

This definition is saying that a matching is optimal if and only if it matches each student with a project that has a highest priority on the student’s preference list than that of the other projects.

If a matching satisfies both *stability* and *optimality*, then it is uniquely existed as the *best matching* [2].
2.2 Current Solution

A linear time algorithm has been proposed to solve the original SPA using appropriate data structures [1]. However, this algorithm does not perfectly solve the problem described in this project. Specifically, it does not allow students work in a group. A group of student may be defined as follows. Let $G = \{G_1, \cdots, G_r\}$ be $r$ groups. Each group $G_i$ in $G$ is a subset of $S$ such that each student $s_k$ in $G$ can exist once only (i.e. a student cannot belong to 2 different groups). It follows that $S \setminus G$ is a subset of students who work individually.

3 Objectives

This project aims to develop and implement a web-based system called the Project Allocation System (PAS) to generate the best matching between students and projects. Students and lecturers can submit their preference lists on the system. The PAS then run an algorithm to find the best matching.

3.1 Scope

The PAS contains following major functions:

1. Student registration. Each student can register as a user in the system.

2. Ranking projects/students. Users are allowed to rank a finite number of projects or students.

3. Generate the best matching. After the system collected preference lists fro all users, the best matching is generated.

4. Administrator panel. For administrator to manage the system. One major function is to approve generated matching.

3.2 Goals

The ultimate goal of this project is to reduce the time and cost in constructing the best matching between students and projects which is primarily subject to their preference lists. Particularly, the administrative cost can be remarkably cut down. The web-based
nature of the PAS allows users to access the system from a range of devices (e.g., laptop, mobile) without having to develop another system on a specific platform.

4 Methodology

4.1 Software Development Process

An unified software development process is used in this project. It features 4 distinct phases with each phase containing iterative and incremental cycles. These phases are Inception, Elaboration, Construction and Transition. The last phase, Transition will be omitted in this project because of the limited time on deploying the system into real-life situation. The details of each phase are given in Table 2.

4.2 Technical Aspect

As the PAS is designed to be a web-based system, both web server and database management system are required. A high-level system architecture diagram is illustrated as below. Essentially, the PAS is based on these free and open source software packages.

![High-level system architecture diagram](image)

**Figure 2:** A high-level system architecture diagram.

4.2.1 Back-end Layer

The PAS will deploy under the GNU/Linux operating system which offers a robust and security platform for software to run.
The PAS uses the Django web framework as its back-end system. The scripting language for the Django is Python. With comprehensive built-in functions in Django, it provides a rapid development platform. For the database system, PostgreSQL is chosen. It is an object-relational database system (ORDS) that is renowned for its reliability and data integrity.

To handle users’ requests, NGINX is chosen for the web server. It is a lightweight and yet a highly scalable server compare with Apache. By adding uWSGI module, it serves as a proxy server to redirect requests to the Django web framework so as to provide dynamic web contents. Together with the PostgreSQL database system, the performance of the PAS will outperform the traditional LAMP stack which comprise of GNU/Linux, Apache web server, MySQL database system and PHP.

### 4.2.2 Front-end Layer

In order to implement a web-based system, 3 core web technologies are used in the PAS. These are HTML, CSS and JavaScript which are all run on the client side, that is, the browser. The details of each technology are as follows:

<table>
<thead>
<tr>
<th>Name</th>
<th>Full name</th>
<th>Major functions on a web page</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTML</td>
<td>Hypertext Markup Language</td>
<td>Outline the structure of a web page, it serves as the building blocks</td>
</tr>
<tr>
<td>CSS</td>
<td>Cascading Style Sheets</td>
<td>Set the visual style to provide a better user interface</td>
</tr>
<tr>
<td>JavaScript</td>
<td>N/A</td>
<td>Provide interactive elements</td>
</tr>
</tbody>
</table>

Table 1: A table listing 3 core technologies used in the PAS.

### 5 Risk, Challenges and Mitigation

Despite the project is mainly about developing the PAS, there are still several challenges. First, the variant SPA introduced in this project might not be able to solve in polynomial time, that is, no polynomial algorithm for this problem. This will greatly affect the efficiency of the PAS. Some assumptions (e.g. work as a group) might have to abandon if it happened.
Second, since only web interface will be implemented, there might have discrepancy between different devices. This will lead to difficulties for users to use the system. It is hoped that by using some well-written web front-end frameworks, the user interface can maintain its consistency.

6 Schedule

The tentative schedule to design and implement the PAS is given in Table 2.

7 Conclusion

The PAS we introduced in this project aims solve the SPA in real-life scenario. The web-based nature of the system allows great flexibility across devices. After obtaining the preference lists from users, the system can construct the best matching efficiently.
<table>
<thead>
<tr>
<th>Date</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 October 2016</td>
<td>Deliverables of Phase 1 (Inception)</td>
</tr>
<tr>
<td></td>
<td>• Detailed project plan</td>
</tr>
<tr>
<td></td>
<td>• Project website</td>
</tr>
<tr>
<td>October 2016</td>
<td>Requirements gathering and analysis</td>
</tr>
<tr>
<td></td>
<td>• Collect user requirements</td>
</tr>
<tr>
<td></td>
<td>• Further study on SPA based on the requirements</td>
</tr>
<tr>
<td></td>
<td>• Implement a prototype to solve the SPA</td>
</tr>
<tr>
<td>November 2016 to</td>
<td>Development of the demo system</td>
</tr>
<tr>
<td>December 2016</td>
<td>• Implement a working web-based demo PAS</td>
</tr>
<tr>
<td></td>
<td>• Design the web-based user interface</td>
</tr>
<tr>
<td>22 January 2017</td>
<td>Deliverables of Phase 2 (Elaboration)</td>
</tr>
<tr>
<td></td>
<td>• Preliminary implementation of the demo system</td>
</tr>
<tr>
<td></td>
<td>• Detailed interim report</td>
</tr>
<tr>
<td>February 2017 to</td>
<td>System Design and Construction</td>
</tr>
<tr>
<td>March 2017</td>
<td>• Refine the demo PAS</td>
</tr>
<tr>
<td></td>
<td>• Implement the administrator user interface</td>
</tr>
<tr>
<td>April 2017</td>
<td>Deployment and Testing</td>
</tr>
<tr>
<td></td>
<td>• Final testing and optimisation</td>
</tr>
<tr>
<td></td>
<td>• Deploy the PAS</td>
</tr>
<tr>
<td>17 April 2017</td>
<td>Deliverables of Phase 3 (Construction)</td>
</tr>
<tr>
<td></td>
<td>• Finalised implementation</td>
</tr>
<tr>
<td></td>
<td>• Final report</td>
</tr>
</tbody>
</table>

Table 2: Tentative schedule.
References
