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PCRS: Personalized Career-Path Recommender System for Engineering Students

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ABSTRACT Choosing a university specialization is a challenging decision for high-school students. Due to the lack of guidance and limited online resources, students base their decisions on subjective perceptions of family and friends. This increases the risk of high university dropout rates, and students changing their university disciplines. To address the aforementioned drawbacks, this research paper presents a Personalized Career-path Recommender System (PCRS) to provide guidance and help high school students choose engineering discipline. The design of PCRS is based on fuzzy intelligence of N-layered architecture and uses students' academic performance, personality type, and extra-curricular skills. The association between personality type and engineering discipline was built using a sample of 1250 engineering students enrolled in seven engineering disciplines at An-Najah National University. PCRS is implemented as a mobile application and it is tested against an evaluation sample of 177 engineers. The sample consists of graduate or undergraduate engineers who are satisfied with their engineering disciplines. The evaluation examined the agreement between the recommendations generated by PCRS and the 177 actual engineering discipline of the sample. The evaluation results proved a slight agreement between the suggested recommendations of PCRS and the actual discipline of the research sample. Hence, PCRS is capable of providing guidance to high-school students who are interested in pursuing their studies in Engineering. The PCRS application is the first career-path recommender to target Palestinian community and other developing countries in the MENA region. The design of PCRS is scalable and it can be expanded in the future to consider other academic majors of higher education.

INDEX TERMS Educational technology, engineering disciplines, fuzzy logic, personalized system, recommender system.

I. INTRODUCTION

Major changes have occurred since the beginning of the 21st century in many aspects of life such as climate changes, rapid technical developments and population-growing crises. The effective solution to those arising challenges has to be innovative, creative and novel. Hence, higher education, and especially engineering education, has to be developed to consider highly-demanded skills such as critical thinking, team-working, and interpersonal skills in addition to the traditional background knowledge [1], [2]. This new formation of engineering education philosophy requires to attract creative students with good communication skills in addition to technical competence in STEM. Such educational development

will raise the quality of university graduates to be more effective, innovative and successful in their career path.

In the Middle East, higher education development is very crucial and necessary due to the high unemployment rates in the region. In a recent study performed by the International Labor Organization [3], the unemployment rate among young population of Arab states is around 20% which is very high compared to the global youth unemployment rate of 11.8%. One factor for such major problem is the gap in competencies between the quality of university graduates and the required competences of the private sector. This gap can be reduced by helping students choose their career path based on their skills, personality type, and educational background knowledge [4]. By combining these three factors in the career decision-making process, graduates with adapted characteristics will be innovative and creative.

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Students start exploring career choices at high school. They develop comprehensive career plans with personal help from their parents, friends, and/or high-school advisors. Providing students with professional advice is essential to help them choose their future career path and it should take into consideration several factors such as; personal and cultural values, personality profile, educational background and expectations of parents, and academic performance.

Parents and friends base their advice on personal experience which does consider student's personal characteristics and skills. Schools on the other hand, have advisors who are trained and qualified to analyze student's personal and academic profile and help them choose the best career path. In developing countries, students rely mainly on parents and family advice. For example, in Palestine the educational system has very slow progress in terms of providing personal advice and support to students due to the instability of the political and economical situation [5]. Public schools provide students with quality education and minimal advise on career paths. Palestinian schools have on average 422 students and one advisor [6]. This makes it difficult for the advisors to provide personal advice to students, and consequently increases the chances of students choosing a wrong career path.

To address the aforementioned drawback in developing countries, this paper presents a Personalized Career-path Recommender System (PCRS) which aims to help high-school students choose their educational discipline and career path by analysing their personal and academic profiles. PCRS focuses on engineering higher education in Palestine since it is among the most chosen faculty by high schools students [7]. And there are several engineering disciplines for students to choose from such as computer, electrical, civil, mechanical, chemical and industrial engineering. A recent problem is noticed at Palestinian universities is that first-year students tend to choose their engineering discipline based on its reputation rather than personal adaptability. As a result, dropout and failure rates among students are increased as well due to wrong career-path decision. For example, enrollment rate in Computer Engineering (CE) at An-Najah National University is sharply increased in the last few years (274 computer engineering students in 2018 compared to 106 students in 2015 [8]). Unfortunately, 43.1% of CE students in 2018 failed to pass to second year. The high dropout rates among first-year students is usually due to the unexpected challenging nature of the courses and that students were not able to fulfill their academic expectations [9]. Hence, PCRS aims at solving such problem by guiding students towards the most suitable discipline to choose based on their personal and academic profile. Hopefully, this will reduce the dropout rates at university levels.

PCRS uses artificial intelligence to conclude the most suitable association between the engineering discipline and the personality and academic profile of the student. Literature review found that no empirical study has been carried out to analyze the association between the engineering different disciplines and students in Palestine nor in the Arab countries

in the MENA region. Therefore, this research aims to identify the association using a sample of 1257 Palestinian engineers from different disciplines. The paper is structured as follows. Section II provides a brief review of related works. The architecture of the PCRS's framework is explained in Section III. Section IV presents the implemented expert recommender system and the obtained evaluation results. Finally, conclusions and future work are depicted in Section V

II. LITERATURE REVIEW

This section provides a comprehensive review on educational expert recommender systems with the focus on career-path recommenders. There are several types and categories of recommender systems designed to support learning for students and teachers. However, the focus of this review will be on personalized fuzzy recommender systems for different disciplines and educational levels. For further details about other types of recommenders, we refer the reader to some excellent reviews from the literature [17]–[19].

The implementation of personalized recommender systems depends on various factors such as personal profile of target users, gender, environmental and cultural background and personality type. For a clearer view of the different types of personalized recommender systems, Table 1 summaries the different recommender systems and their implementation factors and target users.

Some recommender systems were designed to provide educational guidance regarding the management of learning objects such as courses and exercises. For example, a smart course recommender system is proposed in [10] to provide teachers with recommendations to help them better manage their courses based on the different learning styles of students. Another example is a hybrid recommender system [11] for course recommendation with professor and student information dataset to enhance the effectiveness of information access to learners. A personalized group-based recommendation system is implemented in [16] to improve students' search experience on the Web based on their behaviour patterns and competences.

Another objective of personalized recommender systems is to predict the most suitable career choice for students based on their personal background, personality, academic performance and environment [20]. Choosing a career path is a difficult decision high-school students need to take at a very young age. Such a decision is affected by many factors such as; family influence, gender, personality, academic performance, and cultural and financial influence [21]–[23]. Students usually do not have guidance nor experience to help them choose their career path. For example, in engineering there are various disciplines to choose from, such as civil, chemical, computer and electrical, and industrial engineering. Students do not have knowledge on the difference between engineering disciplines which affects their choice negatively [24].

An example of a career-path recommendation model was proposed in [12] to direct students towards the most suitable

TABLE 1. A review of educational expert fuzzy recommenders.

	Factors	Targeted sample
Smart Recommender System for Learning objects [10] Pers: Course selection recommender [11]	Personal learning patterns of students	Canada
Career-path recommender for engineering students [12]	Personal information, knowledge and expertise	India
Career-path recommender for high-school students [13] Career-path recommender [14]	student’s interest and skills, influence from peers and family Age, gender, grades and peer influence	India Philippines
GSTEM-CAT: university-program recommender [15]	Career test	Malaysia
Personalized group-based recommender [16]	student’s personality type and knowledge test Personalized recommendations based on students’ competences and behaviour	Philippines Malaysia

engineering stream. The model built the recommendations based on a fuzzy logic to compare the similarity between career characteristics and students’ preferences in addition to the influence of their environment. A similar fuzzy logic recommender system was presented in [13] to guide senior high-school students through their career decision-making process by considering factors such as age, gender, grade, and peers’ influence.

As there is a relationship between personality types and career development and success [25]–[27], personality-based recommender systems were proposed to guide students in their search towards future careers [14], [15]. Example of such recommender systems is the one proposed in [15] which is a fuzzy recommender system designed to help college students to choose the appropriate university program based on their personality type and knowledge strength.

The aforementioned recommender systems are designed to provide career recommendation for students while considering various factors. However, none is designed to consider students in developing countries such as Palestine, where the economical and political situations are affecting the education quality and the students’ personality and their effects on career choice. Therefore, this paper implements a career-path fuzzy recommender system for Palestinian senior high-school students based on personal interests, skills, academic performance and personality type. The specifics of the proposed recommender system are explained in the following sections.

III. FRAMEWORK OF THE RECOMMENDER SYSTEM

Providing a career and educational speciality recommendation for high school students is complex task. Unfortunately, most educational systems in Middle Eastern countries do not provide career analysis for high school students to help them choose their future career path. After finishing high school, students start looking up for a university discipline mostly based on their academic performance hoping that their choice will lead them to a successful career path. Students also seek help from their family, social advisors at schools and their colleagues. However, the decisions are subjective and does not take into account the personality type, and extra-curricular skills in addition to the academic performance.

This paper proposes a Personalized Career-path Recommender System (PCRS) which help high school students choose best candidate engineering discipline such as; Computer Engineering, Electrical Engineering, Civil

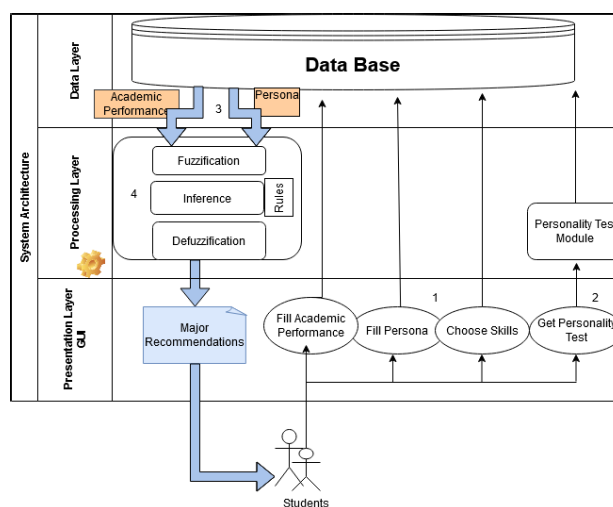


FIGURE 1. Framework architecture of PCRS.

Engineering, Architecture, Industrial Engineering, Mechanical Engineering, and Chemical Engineering. PCRS’s design is adapted to the Palestinian educational system, which is similar in many ways to the other countries in the Middle East region.

The recommender system exploits the personal and educational information retrieved from the target users, and it is implemented based on four main phases, as shown in Figure 1:

- 1) Obtaining student’s personal information including gender, high school grades in STEM courses, and a list of extra-curricular interests.
- 2) Determining student’s personality type based on a self-administered personality test.
- 3) Processing input data to construct a personal and academic profile for each student.
- 4) Building a fuzzy recommender system to provide students with personalized and user-specific ranking of engineering disciplines.

The first and second phases are used to collect personal information on each student. The input data from the first phase is static and filled directly by the users. While the data from the second phase is derived from a personality test so as to determine the personality type of each student. This phase uses the Myers–Briggs Type Indicator (MBTI) [28] as a personality test. The third phase helps in creating personalized

profiles and processing the data to be used as input to the fuzzy system in the fourth phase. The recommendations are generated in the last phase by implementing a generic fuzzy recommender system. The output of this phase is a sorted list of possible engineering disciplines according to a suitability ranking derived from the personal and academic profile of students.

A. INPUT DATA COLLECTION

The objective of PCRS is to mimic the logic of high-school advisors and provide guidance and recommendations to students after analyzing their academic performance in addition to their personal profiles. Hence, PCRS starts by collecting data which is categorized as follows; personal information, academic performance, and personality type. Those information are used to construct personal profiles for each student which will be used by the recommender.

1) PERSONAL INFORMATION

The collected personal information of each user are the gender, the extra-curricular skills and personal interests. Information about the gender can be tied to the employment rates of engineering disciplines in Palestine among male and female engineers. Hence, the possible employment rate of engineers after graduation is taken into consideration when recommendations are generated. The employment rates are retrieved from the official Palestinian Central Bureau of Statistics (PCBS) and the statistical archive of Palestinian universities.

extra-curricular activities and personal skills are retrieved from students to provide PCRS with additional important information about their personal profiles and their interests. Examples of such activities are artistic skills, computer-related skills, sportive skills, community services and volunteering. The mapping between the extra-curricular activities and engineering disciplines will be further explained in Section III-B.

2) ACADEMIC PERFORMANCE

In Palestinian educational system, the academic Performance of high-school students is evaluated based on major STEM topics which are Mathematics, Physics, Chemistry and Information Technology (IT). Usually, a student who achieves excellent grades in those topics is directly advised to enroll in medical or engineering schools. Further explanations will be provided in Section III-B.

3) PERSONALITY TEST (MBTI)

The Myers-Briggs Type Indicator (MBTI) is a popular psychology test to detect the personality of people based on self-administered questions. MBTI identifies people as extroverted (E) or introverted (I), sensing (S) or intuitive (N), thinking (T) or feeling (F), and judging (J) or perceiving (P). Combinations of the four preferences determine personality types which are identified as 16 possible four-letter codes (such as ESFJ, ENFP, INTP, and ISFJ, ...).

Many researches from the literature had analyzed the relationship between MBTI personality types and career choices in specific domains such as medical sector and engineering. [29]–[31].

In this phase, the student is asked to conduct a self-administered questionnaire and answer a number of psychological questions with short answers. Then MBTI test analyzes the answers and determines the type of personality. A major contribution of this paper is to analyze the personality types of students and establish an association between personality type and engineering disciplines in Palestine.

B. INPUT DATA PROCESSING

The data processing phase is necessary for PCRS to convert the personal input data into numerical values that can be used as input variables for the membership functions of the fuzzy-logic system. Although qualitative inputs are acceptable for fuzzy logic systems, the quantifying process of inputs is necessary to calculate a common score to be used for all engineering disciplines. As a result, PCRS's design can be easily extended into other career specialities by following the same proposed processing phase. Another importance of the processing phase is to have a common membership function for fuzzy-logic system to produce a different recommendation for each engineering discipline, and no need to have a membership function per discipline.

The data processing phase is divided into two main parts; the first is for the academic profile and the second part is for the personal profile of the users.

1) PROCESSING OF ACADEMIC PERFORMANCE

Starting with the academic profile, students are required to enter their high-school grades in the STEM topics. This is used to calculate a weighted average of the grades for each discipline. In Palestine, the scientific branch of the high school consists of four major STEM topics; mathematics, physics, chemistry and information technology. Usually, students with excellent academic performance in those topics are eligible to enrol in engineering departments. Other topics such as Languages, biology and social studies are excluded from this research since they have no direct impact on the focus of this study which is the engineering department.

The relation between academic performance in STEM studies in high schools (prior to university education) and the chosen career path in science had been discussed in many previous researches [32]–[34]. In this research, a association between specific STEM high-school topics and engineering disciplines is derived. The association is done based on 1) the related literature and after 2) consulting the course plan of engineering disciplines from various universities, and also after 3) consulting with educational experts in each field of engineering. As shown in Table 2, the most important high school topics are mapped with engineering disciplines. It is worth mentioning that high-school STEM courses are from the Palestinian educational baccalaureate, which consists of

TABLE 2. STEM courses weights mapped to engineering disciplines.

Discipline Courses	Mathematics	Physics	IT	Chemistry
Computer Engineering	2	1	2	1
Electrical Engineering	2	2	2	1
Civil Engineering	2	2	1	1
Architecture	2	2	1	1
Chemical Engineering	2	1	1	2
Industrial Engineering	2	1	2	1
Mechanical Engineering	2	2	1	1

major STEM courses which are Mathematics, Physics, Information Technology, and Chemistry.

The objective of this phase is to calculate a personalized score for academic performance for each engineering discipline based on the entered STEM grades. The student's academic score will be used in the next phase as an input to the membership function of the fuzzy logic of PCRS. An example of the STEM courses-discipline association is the computer engineering discipline (refer to Table 2), the most important topics from high school courses are Mathematics and Information Technology. Other courses such as Physics are useful as well but with less importance.

The Weighted average is used to calculate the academic score for each discipline per student. The use of weighted average is more accurate than simple average calculations and allows to prioritize specific courses based on their importance for a given engineering discipline. The following equation explains the calculation of the academic score of a given student s for a specific engineering discipline d :

$$Academic(s, d) = \frac{\sum_i^n (gradeList(s, i) \times weight(i, d))}{\sum_i^n weight(i, d)} \quad (1)$$

where $gradeList(s, i)$ is the i^{th} grade of the list of STEM high-school courses of student s , and $weight(i, d)$ is the weight of the course i for discipline d . The weights are derived from Table 2, where courses mapped to a specific discipline have double the rate of less important courses. For example, computer engineering is mapped to Mathematics and IT. Hence, the weights of those two courses are set to 2, while Physics and Chemistry have a weight of 1.

2) PROCESSING OF PERSONAL PROFILE (PERSONA)

The processing phase for persona score represents the personal profile score of each student. The profile includes personality type, gender and extra-curricular skills. The persona score allows PCRS to generate recommendations for each engineering discipline based on the personal profile of the students in addition to the academic performance. Hence, the generated recommendations become more accurate and personalized.

Many researches [35]–[37] showed that there is an association between extra-curricular activities performed by students in high schools and future career choice and personality. Accordingly, it is essential to consider the extra-curricular activities of students as an indicator and a factor to generate a suitable future studying discipline. Based on the Palestinian

culture, this research considered a number of extra-curricular activities which are popular among high school students. Those activities are summarized as sports, arts, computer & electronics clubs, and volunteering & community services. After consulting with educational experts in high school and expert engineers, and based on researches from literature [38], [39], an association between these activities and engineering disciplines is derived. For example, computer skills are very important for computer and electrical engineers, while artistic skill is very good skill for architecture, and so on.

The type of personality is the major factor in determining the engineering career path. Although there are some studies [26], [40] that analyzed the association between career type and personality type, fewer studies focused on specific disciplines in a certain career such as engineering. Moreover, the personality-career association is culture-dependent [26], [41], so this research is the first to derive a personality-career association for the Palestinian community. The analysis is based on a research sample of 1257 engineering students and graduates from An-Najah National University (60% are females and 40% are males) who volunteered to take part in the experiment. The sample was collected by broadcasting an email to undergraduates and graduate engineering students from An-Najah national university which explains the aim of the research study and encourages them to participate. The email had a questionnaire attached which the interested participants used to agree to be part of the research study. The data was collected in January 2020 and the participants were asked to provide their personal information, grades in STEM high-school courses and their engineering discipline. Also, they are asked to do an online MBTI personality test. As explained above in Section III-A, the MBTI test is able to determine the student's personality type. The participants were officially informed that they are part of an experiment and that the collected data will be used in the analysis anonymously. The data collection process was approved by the committee on the Ethics of Research on Human Beings at An-Najah National University in 2019. All results are saved in the database and analyzed to create an association between the personality types and engineering disciplines in Palestine.

The participants of the research sample varied in their engineering disciplines as shown in Figure 2. The majority of the research sample consisted with computer engineers (33.1%) and followed directly with civil engineers (26.2%). Both disciplines form more than half of the research sample which is consistent with the fact that those two disciplines are the largest at An-Najah National University. Then industrial engineering students were 13.6% of the sample. The remaining engineering disciplines formed a little less than third of the sample. Accordingly, the research sample is well-distributed and can be used for the analysis.

In this research, personal information for each student was collected. The analysis of personality types and its relationship with engineering disciplines is shown in Table 3.

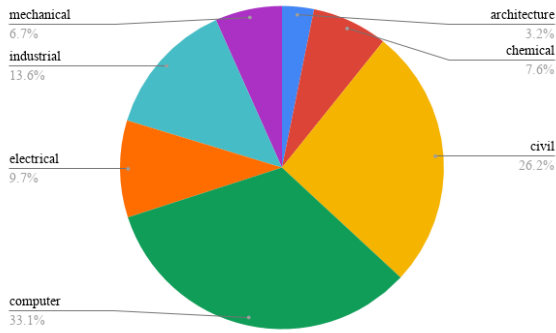


FIGURE 2. Engineering disciplines of research sample.

TABLE 3. Personality types of engineering students from research sample.

	Analysts	Diplomats	Sentinels	Explorers
Computer	20%	6.8%	55.9%	17.3%
Architecture	40.6%	9.4%	40.6%	9.4%
Chemical	16.5%	12.4%	48.4%	22.7%
Industrial	18%	5.8%	62.2%	14%
Civil	16.1%	8.8%	59.3%	15.8%
Electrical	12.3%	5.7%	66.4%	15.6%
Mechanical	13.1%	3.6%	63.1%	20.2%

The results of this analysis is in accordance with the ones found in [42], [43] in which they stated that engineering students are mostly Sentinels and Analysts. However, the analysis of our research sample was more detailed regarding the personality-discipline association. Also, the papers from literature did not specify all types of engineering students but they focused on certain disciplines such computer engineering [42]. More analysis is done on engineering students in [43] where they analyzed the personality types of chemical engineering students based on MBTI personality test.

A main contribution of this research is to further analyze the personality type of engineers based on their discipline. Based on Tables 3 and 4, the personality score for each

student per discipline can be calculated. When the type of personality is determined by the MBTI test in PCRS, the personality score for each discipline is calculated by multiplying percentage of personality category with the percentage of the exact personality type. For example, if a personality type is ISTJ (which is from the Sentinels category), then the score for computer engineering is calculated as $0.559 * 28.6\% = 15.98\%$. This number means that 55.9% of computer engineers are Sentinels and from this category, 28.6% are ISTJ. This score can be calculated for each engineering disciplines. The persona score for each student and per discipline is calculated based on the personality score and the extra-curricular activities with a ratio 2:1. This means that the personality score is almost 67% of the persona score and the activities are 33%.

As a result and for each user, two scores are defined for each engineering disciplines, one for persona and the other for academic performance. The same calculations can be applied for each different disciplines but with different scores. The following section explains how these scores are used as inputs for the fuzzy logic system of PCRS and how this processing phase helped in simplifying the fuzzy-logic member functions and rules.

C. IMPLEMENTATION OF THE FUZZY-LOGIC SYSTEM

PCRS is designed by using Fuzzy-logic as its core intelligence. This technique was introduced many years ago to be used on systems with qualitative input observations and imprecise output with partial truth [44]. Fuzzy logic was introduced by Lotfi Zadeh in 1965 [45] as a computing approach based on degrees of truth rather than the boolean logic (1 or 0). It handles uncertainty, which are found in most real-life problems, by building fuzzy inference systems.

Fuzzy system consists of three parts; 1) a fuzzifier which converts the input to a linguistic variable using the membership functions such as triangular, sigmoid, trapezoidal, or gaussian, 2) an inference engine which uses If-Then rules to convert the fuzzy input to the fuzzy output. And 3) a

TABLE 4. Engineering disciplines distribution over the 16 personality types of the MBTI test.

	Analysts				Diplomats			
	INTJ	INTP	ENTJ	ENTP	INFJ	INFP	ENFJ	ENFP
Computer	33.3%	13.1%	45.2%	8.4%	44.9%	6.9%	31%	17.2%
Architecture	46.2%	0.2%	46%	7.6%	33.1%	0.2%	66.4%	0.3%
Chemical	37.5%	0.2%	43.6%	18.7%	16.6%	0.1%	41.6%	41.7%
Industrial	45.2%	6.5%	38.7%	9.6%	30%	20%	30%	20%
Civil	26.4%	5.7%	50.9%	17%	37.9%	24.2%	20.7%	17.2%
Electrical	13.3%	13.3%	53.4%	20%	0.2%	14.1%	71.4%	14.3%
Mechanical	54.5%	18.2%	9.1%	18.2%	66.6%	0.1%	33%	0.3%
	Sentinels				Explorers			
	ISTJ	ISFJ	ESTJ	ESFJ	ISTP	ISFP	ESTP	ESFP
Computer	28.6%	13.3%	44%	14.1%	25%	12.5%	40.3%	22.2%
Architecture	46%	0.2%	46.2%	7.5%	0.1%	0.4%	66.3%	33.3%
Chemical	23.4%	8.5%	44.7%	23.4%	18.2%	9%	40.9%	31.9%
Industrial	18.7%	11.3%	60.7%	9.3%	20.8%	4.2%	58.3%	16.7%
Civil	33.3%	6.1%	49.3%	11.3%	32.7%	9.6%	38.5%	19.2%
Electrical	29.6%	1.2%	53%	16.2%	26%	0.3%	47.4%	26.3%
Mechanical	34%	3.8%	54.7%	7.5%	11.8%	5.9%	82.1%	0.2%

TABLE 5. Fuzzy rules.

Persona	Academic Performance				
	fail	satisfactory	good	very good	excellent
Lowly Appropriate	inadequate	inadequate	inadequate	neutral	neutral
Moderately Appropriate	inadequate	neutral	neutral	neutral	adequate
Highly Appropriate	inadequate	neutral	neutral	adequate	adequate

defuzzifier which converts the fuzzy output of the inference engine to output using membership functions similar to the ones used by the fuzzifier.

The choice of fuzzy logic intelligence to implement PCRS comes from the main vision of the work which is to mimic the work of a school advisor who can provide a personalized and suitable recommendation to students based on their academic and personal profiles. Hence, the fuzzy-logic is used to provide a sorted list of recommended choices of future career disciplines among which the student can choose from.

The fuzzy system lies in the processing layer of the recommender system, as shown in Figure 1. The fuzzy-logic system is designed as a universal core for all engineering disciplines. For each student, corresponding processed data (academic score and persona score) of a specific engineering discipline is entered to the fuzzy-logic, and the fuzzy logic determine a personalized rate for it. This process will be repeated for all seven engineering disciplines considered in PCRS.

In this research, the fuzzy system is designed based on the Mamdani inference, which is known to be intuitive and well-suited to human cognition. The fuzzy system consists of a set of fifteen if-then rules that model the qualitative aspects of human reasoning in case of uncertainty (refer to Table 5). However, there are no specific standard which defines how human experience can be transformed into fuzzy rules. Moreover, the membership functions of the fuzzy system are the building blocks of its theory. They are used to determine the effect of the problem’s inference on the system. It is important to tune the membership functions for a good design of the system by minimizing the error rates.

The fuzzy set of PCRS consists of two input membership functions, one for persona input score and the other is for academic performance score. The inputs for both membership functions calculated by the processing phase which is previously described in Section III-B.

The persona membership function (shown in Figure 4) is designed based on the numerical distribution of persona scores which is shown in Figure 3. The boxplot chart is derived from the personality analysis of the research sample while exploiting possible persona scores of all disciplines. It is possible to notice that the range of the persona score is between 12% and 45%. Accordingly, the membership function is a trapezoidal type and it is divided into three main intervals: lowly, moderately and highly appropriate. The ranges of the intervals are derived from the persona distributions provided in Figure 3. For example, the lowly-appropriate range persona score is between 0% and 20% based on the first quartile of the boxplot. The median of persona distribution is 25%,

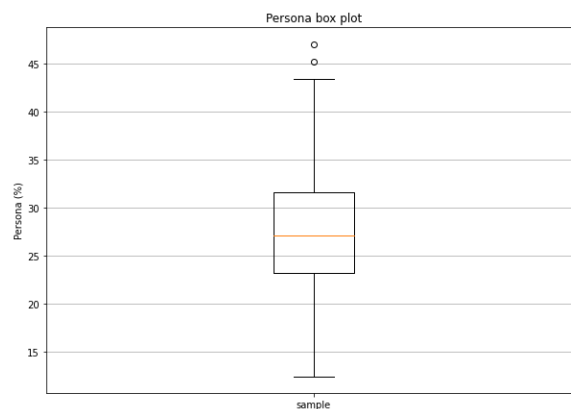


FIGURE 3. Boxplot of the persona score distribution.

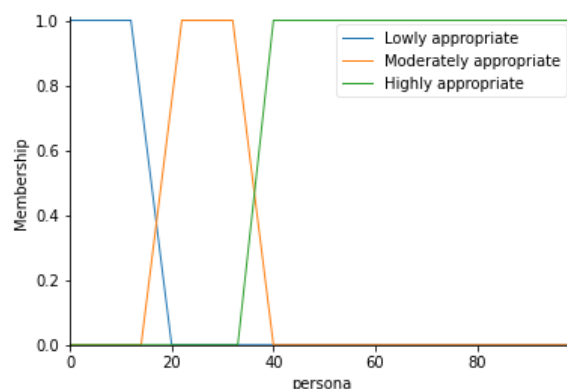


FIGURE 4. Membership function of the persona score.

which is close to the midpoint of the moderately-appropriate range. However, the highly-appropriate range starts at a score of 33% and reaches its highest value at 40%. Hence, any persona score which is higher than 40% is considered highly-appropriate for a specific engineering discipline.

The second membership function is for the academic performance. As shown in Figure 5, this membership function is distributed to identify five categories. According to the Palestinian educational system, an academic performance less than 50% is considered as a “fail” (the first category). The remaining grade distribution is divided into four categories to represent the performance scale from satisfactory up to excellent.

The output membership function (Figure 6) represents the three main possibilities of the suitability for a given engineering discipline. These possibilities are categorized as bad,

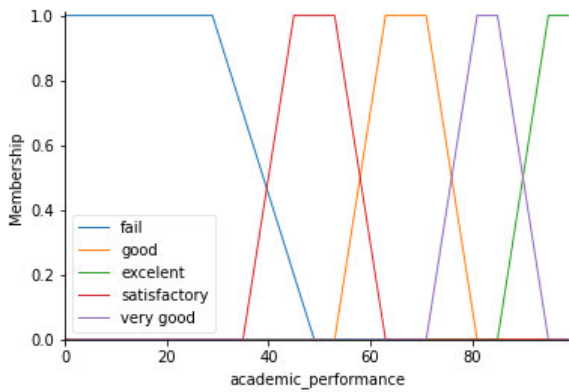


FIGURE 5. Membership function of the academic score.

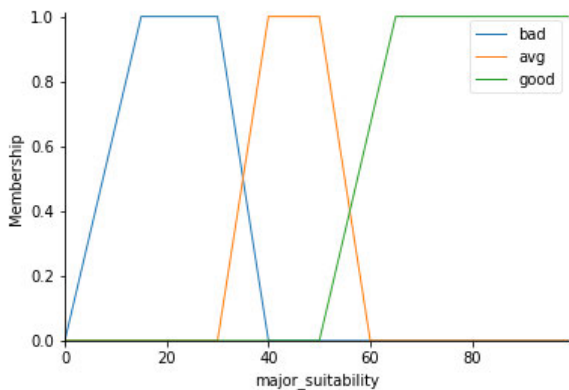


FIGURE 6. The output Membership function of the fuzzy system.

average and good. The chosen defuzzification is the Centroid method which determines the center point of the area of the fuzzy set.

The global design of PCRS reduced the number of required fuzzy rules. The membership functions are designed to be universal for all engineering disciplines instead of having specific membership functions for each disciplines. The rules were derived after consulting with educational experts to determine the suitability degree of an engineering discipline based on persona and academic scores for each student. A total of 15 rules are derived and they are shown in Table 5.

In order for PCRS to provide an engineering discipline recommendation, the following steps will be repeated for each engineering discipline:

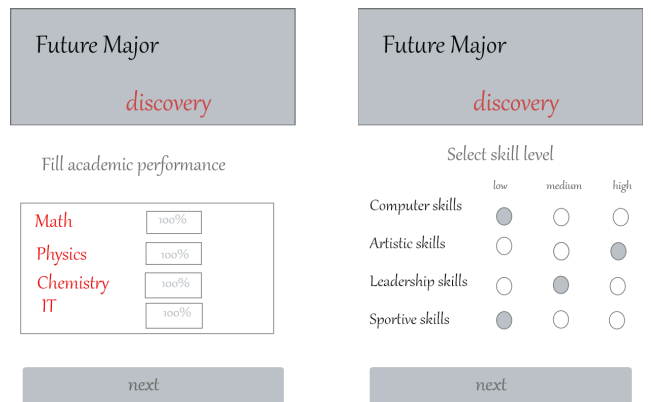
- 1) The academic and personal scores of student are processed based on the engineering discipline.
- 2) The processed scores are entered as input data to corresponding membership functions.
- 3) a suitability rate is generated by the fuzzy logic based on input data.
- 4) Steps (1-3) are repeated for all engineering disciplines.
- 5) The suitability rates of all disciplines are sorted in an ascending order and presented to the student as the output of PCRS.

IV. PCRS IMPLEMENTATION AND EVALUATION

This section illustrates the implementation process of PCRS and how the system is evaluated.

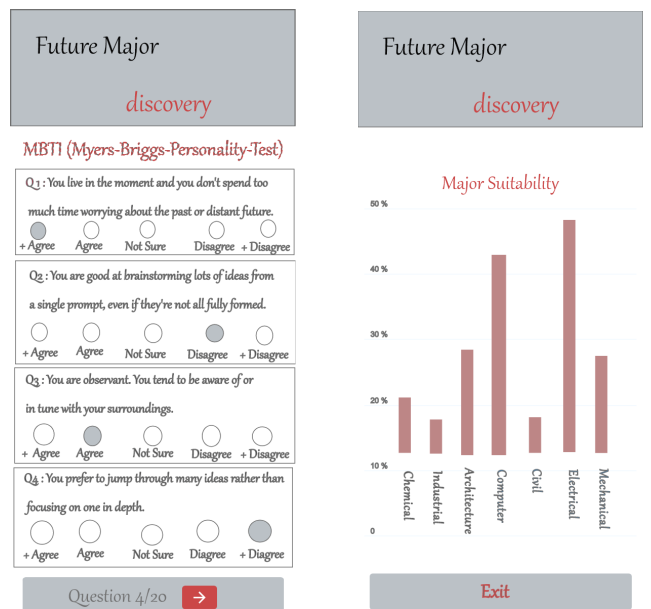
A. SYSTEM IMPLEMENTATION

The PCRS's design is a user-friendly mobile application to be easily used by high-school students. The crux of implementation of PCRS is designed based on the N-layered architecture style. Thus, non-functional requirements regarding system's security, usability, performance and availability were achieved. The design's objective is to have clear views for data-collection and recommendation/generation processes as shown in Figure 7. The back-end of PCRS was implemented based on Spring-Boot-based-Java framework to acquire the non-functional requirements mentioned above.



(a) Interface of STEM grades.

(b) Interface of extra-curricular activities.



(c) Interface of personality test.

(d) Output interface.

FIGURE 7. Implemented Application of the Recommender system.

PCRS's application starts by asking the user to enter high-school grades of STEM courses (Mathematics, Physics, Chemistry and IT). The entered grades should be out of 100%. After that, the user has to specify the extra-curricular activities such as sports, art, computer-related activities and volunteering (more activities can be added when considering other university disciplines or career choices). Finally, an MBTI test is provided as a self-administered questionnaire to analyze the personality type. The MBTI test consists of 21 questions randomly chosen from a data-set of 70 questions.

The output of the PCRS application is a bar plot (Figure 7(d)) to show the suitability rates of engineering disciplines after applying the fuzzy logic of the system. The chart aims to provide the user with clear results in a simple way. The user can compare the suitability rates of all engineering disciplines and decide which is the most suitable discipline to choose. PCRS's design is intended to be user-friendly and easy to be used without the need of user's authentication or registration. On the other hand, the application can be easily expanded to provide recommendations for other specialities and disciplines by expanding the fuzzy logic core without changing the system's architecture.

B. SYSTEM EVALUATION

This section presents the experiment carried out to evaluate the PCRS. The evaluation test was performed on a group of 177 engineers who volunteered to take part in the experiment. The sample was collected by broadcasting an email to undergraduates and graduate engineering students from An-Najah national university which explains the aim of the research study and encourages them to participate. The email had a questionnaire attached which participants used to fill their email addresses once they agreed to be part of the research study. 177 undergraduate and graduate students filled the questionnaire and showed their interest in participation. The sample consisted from 61% females and 39% males, and the participants specialized in different engineering disciplines (the distribution is shown in Figure 8). Participants answered a 5-point Likert scale (1: bad, to 5: excellent) question which aimed to assess their engineering

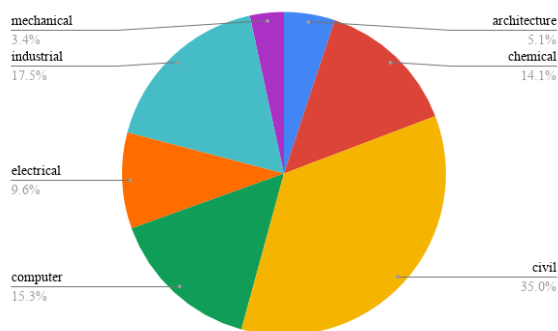


FIGURE 8. Engineering disciplines of evaluation sample.

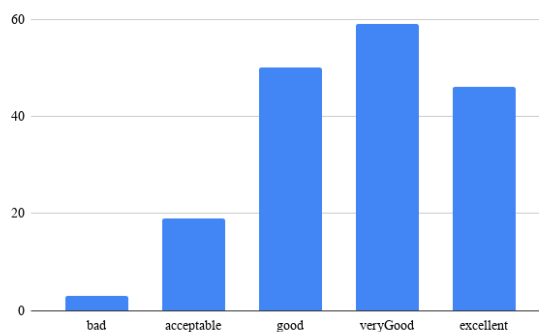


FIGURE 9. Student's satisfaction towards career-path choice.

discipline satisfaction. Figure 9 illustrates that participants were satisfied with their chosen engineering discipline and career-path (the average ranking score is 3.0).

Based on the approval of the committee on the Ethics of Research on Human Beings at An-Najah National University in 2019, participants were asked to use PCRS and they provided their personal information and their academic grades anonymously. Also, they passed a self-administered MBTI test to determine the personality types.

After that, PCRS was evaluated to examine the agreement between the recommendations generated by the system and the actual engineering discipline of the sample. In order to do so, Cohen's kappa was used to determine the agreement between recommender output and students' current specializations. The results revealed that there is a slight agreement between them ($\kappa = 0.23$, 95 % CI, $p < 0.05$). The agreement level is affected by the small number of participants in the evaluation sample.

V. CONCLUSION

In this research, a Personalized Career-path Recommender System (PCRS) is designed to help future engineering students choose their discipline based on various factors such as the academic performance, the personality type, extra-curricular activities. These factors are important to generate personalized recommendations based on the profile of students where individual characteristics are taken into consideration. The main objective of PCRS is to mimic the role of professional advisors who help students take this hard decision by analyzing their academic and personal profiles. The main advantage of the PCRS's design is to consider high-school students in developing countries where educational and professional guidance in schools is limited.

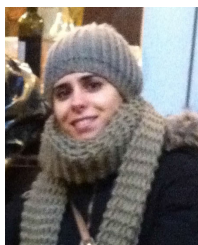
The design of PCRS is based on a fuzzy-logic intelligent with two main input parameters; academic performance and personal profile. In order to derive the association between engineering disciplines and personality types in Palestine, a research analysis was carried out on a sample of 1257 Palestinian participants. Finally, a slight agreement between the recommendations of PCRS and the actual career choice was proved based on an evaluation sample of 177 engineers from different engineering disciplines. In the future,

the evaluation sample will be increased so as to enhance the agreement results of the evaluation test.

In the future, PCRS can be extended to consider more university departments and disciplines other than engineering. Also, the recommendations can be enhanced to consider social-economic factors such as employment rates, economical situation and parent's background specially in developing countries such as Palestine.

REFERENCES

- [1] M. Glenn, "The future of higher education: How technology will shape learning," New Media Consortium, Austin, TX, USA, Tech. Rep. ED505103, 2008.
- [2] P. C. Wankat and L. G. Bullard, "The future of engineering education—Revisited," *Chem. Eng. Educ.*, vol. 50, no. 1, pp. 19–28, 2016.
- [3] I. L. Organization. *Employment Promotion (Arab States)*. [Online]. Available: <https://www.ilo.org/beirut/areasofwork/employment-policy/lang-en/index.htm>
- [4] U.-C. Klehe, J. Zikic, A. E. van Vianen, J. Koen, and M. Buyken, "Coping proactively with economic stress: Career adaptability in the face of job insecurity, job loss, unemployment, and underemployment," *Role Econ. Crisis Occupational Stress Well Being*, vol. 10, pp. 131–176, Jun. 2012.
- [5] S. Nicolai, *Fragmented Foundations: Education and Chronic Crisis in the Occupied Palestinian Territory*. ERIC, Paris, France, 2007.
- [6] P. C. B. of Statistics. (2019). *Selected indicators for education in palestine by level of education and region for scholastic Year*. [Online]. Available: http://www.pcbs.gov.ps/Portals/_Rainbow/Documents/Education2018_E.html
- [7] (2017). *Educational Fields and Labor Market for Persons Aged 20-29 Years*. [Online]. Available: <http://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=3179>
- [8] Q. Unit. *Abet Accredited Engineering Programs*. Accessed: Jul. 1, 2020. [Online]. Available: <https://eng.najah.edu/en/quality-unit/abet-accredited-engineering-programs/>
- [9] I. O. Pappas, M. N. Giannakos, and L. Jaccheri, "Investigating factors influencing Students' intention to dropout computer science studies," in *Proc. ACM Conf. Innov. Technol. Comput. Sci. Edu. (ITiCSE)*, 2016, pp. 198–203.
- [10] M. M. El-Bishouty, T.-W. Chang, S. Graf, Kinshuk, and N.-S. Chen, "Smart e-course recommender based on learning styles," *J. Comput. Edu.*, vol. 1, no. 1, pp. 99–111, Mar. 2014.
- [11] Z. Gulzar, A. A. Leema, and G. Deepak, "PCRS: Personalized course recommender system based on hybrid approach," *Procedia Comput. Sci.*, vol. 125, pp. 518–524, 2018.
- [12] P. Verma, S. K. Sood, and S. Kalra, "Student career path recommendation in engineering stream based on three-dimensional model," *Comput. Appl. Eng. Edu.*, vol. 25, no. 4, pp. 578–593, Jul. 2017.
- [13] M. C. B. Natividad, B. D. Gerardo, and R. P. Medina, "A fuzzy-based career recommender system for senior high school students in k to 12 education," in *IOP Conf., Mater. Sci. Eng.*, vol. 482, Mar. 2019, Art. no. 012025.
- [14] T. R. Razak, M. A. Hashim, N. M. Noor, I. H. A. Halim, and N. F. F. Shamsul, "Career path recommendation system for UiTM perlis students using fuzzy logic," in *Proc. 5th Int. Conf. Intell. Adv. Syst. (ICIAS)*, Jun. 2014, pp. 1–5.
- [15] B. E. V. Comendador, W. F. C. Becbec, and J. R. P. D. Guzman, "Implementation of fuzzy logic technique in a decision support tool: Basis for choosing appropriate career path," *Int. J. Mach. Learn. Comput.*, vol. 10, no. 2, pp. 339–345, Feb. 2020.
- [16] M. M. Rahman and N. A. Abdullah, "A personalized group-based recommendation approach for Web search in E-Learning," *IEEE Access*, vol. 6, pp. 34166–34178, 2018.
- [17] A. Dutt, M. A. Ismail, and T. Herawan, "A systematic review on educational data mining," *IEEE Access*, vol. 5, pp. 15991–16005, 2017.
- [18] R. Bodily and K. Verbert, "Review of research on student-facing learning analytics dashboards and educational recommender systems," *IEEE Trans. Learn. Technol.*, vol. 10, no. 4, pp. 405–418, Oct. 2017.
- [19] H. Drachler, K. Verbert, O. C. Santos, and N. Manouselis, "Panorama of recommender systems to support learning," in *Recommender Systems Handbook*. Boston, MA, USA: Springer, 2015, pp. 421–451.
- [20] A. Shumba and M. Naong, "Factors influencing students' career choice and aspirations in South Africa," *J. Social Sci.*, vol. 33, no. 2, pp. 169–178, 2012.
- [21] A. S. Kazi and A. Akhlaq, "Factors affecting students' career choice," *J. Res. Reflections Educ. (JRRE)*, vol. 11, no. 2, pp. 187–196, 2017.
- [22] R. Palos and L. Drobot, "The impact of family influence on the career choice of adolescents," *Procedia-Social Behav. Sci.*, vol. 2, no. 2, pp. 3407–3411, 2010.
- [23] P. Akosah-Twumasi, T. I. Emeto, D. Lindsay, K. Tsey, and B. S. Malau-Aduli, "A systematic review of factors that influence youths career choices—the role of culture," in *Frontiers in Education*, vol. 3. Lausanne, Switzerland: Frontiers, 2018, p. 58.
- [24] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice," *J. Eng. Edu.*, vol. 105, no. 2, pp. 312–340, Apr. 2016.
- [25] P. Rosati, "Academic progress of Canadian engineering students in terms of MBTI personality type," *Int. J. Eng. Educ.*, vol. 14, no. 5, pp. 322–327, 1998.
- [26] P. Rosati, "Student retention from first-year engineering related to personality type," in *Proc. IEEE Frontiers Edu. Conf. (FIE)*, Nov. 1993, pp. 37–39.
- [27] J. Reynolds, D. R. Adams, R. Ferguson, and P. Leidig, "The personality of a computing major: It makes a difference," in *Proc. EDSIG Conf.*, 2016, pp. 2473–3857.
- [28] I. Briggs-Myers, "Myers-Briggs type indicator (MBTI)," Consulting Psychologists Press, Palo Alto, CA, USA, Tech. Rep., 1985.
- [29] A. Garden, "Relationships between MBTI profiles, motivation profiles, and career paths," *J. Psychol. Type*, vol. 41, pp. 3–16, 1997.
- [30] K. R. Kelly and W.-C. Lee, "Relation of psychological type to career indecision among university students," *J. Psychol. Type*, vol. 64, no. 2, pp. 11–20, 2005.
- [31] N. Saka, I. Gati, and K. R. Kelly, "Emotional and personality-related aspects of Career-Decision-Making difficulties," *J. Career Assessment*, vol. 16, no. 4, pp. 403–424, Nov. 2008.
- [32] W. Tyson, R. Lee, K. M. Borman, and M. A. Hanson, "Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment," *J. Edu. Students Placed Risk (JESPAR)*, vol. 12, no. 3, pp. 243–270, Oct. 2007.
- [33] X. Wang, "Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support," *Amer. Educ. Res. J.*, vol. 50, no. 5, pp. 1081–1121, 2013.
- [34] J. Knowles, T. Kelley, and J. Holland, "Increasing teacher awareness of STEM careers," *J. STEM Educ.*, vol. 19, no. 3, pp. 56–64, 2018.
- [35] A.-S. Denault, C. F. Ratelle, S. Duchesne, and F. Guay, "Extracurricular activities and career indecision: A look at the mediating role of vocational exploration," *J. Vocational Behav.*, vol. 110, pp. 43–53, Feb. 2019.
- [36] B. Lawhorn, "Extracurricular activities," *Occupational Outlook Quart.*, vol. 9, pp. 16–21, Mar. 2008.
- [37] N. Darling, "Participation in extracurricular activities and adolescent adjustment: cross-sectional and longitudinal findings," *J. Youth Adolescence*, vol. 34, no. 5, pp. 493–505, Oct. 2005.
- [38] O. Dalrymple and D. Evangelou, "The role of extracurricular activities in the education of engineers," in *Proc. Int. Conf. Eng. Educ.*, 2006, pp. 24–30.
- [39] B. E. Woolnough, "Factors affecting students' choice of science and engineering," *Int. J. Sci. Edu.*, vol. 16, no. 6, pp. 659–676, Nov. 1994.
- [40] M. Coetzee and N. Martins, "Organisational culture, employee satisfaction, perceived leader emotional competency and personality type: An exploratory study in a South African engineering company," *SA J. Hum. Resource Manage.*, vol. 5, no. 2, pp. 20–32, 2007.
- [41] S. V. Paunonen and M. C. Ashton, "The structured assessment of personality across cultures," *J. Cross-Cultural Psychol.*, vol. 29, no. 1, pp. 150–170, Jan. 1998.
- [42] J. Teague, "Personality type, career preference and implications for computer science recruitment and teaching," in *Proc. 3rd Australas. Conf. Comput. Sci. Edu. (ACSE)*, 1998, pp. 155–163.
- [43] R. M. Felder, G. N. Felder, and E. J. Dietz, "The effects of personality type on engineering student performance and attitudes," *J. Eng. Edu.*, vol. 91, no. 1, pp. 3–17, Jan. 2002.
- [44] L. A. Zadeh, G. J. Klir, and B. Yuan, *Fuzzy Sets, Fuzzy Logic, and Fuzzy Systems: Selected Papers*, vol. 6. Singapore: World Scientific, 1996.
- [45] L. A. Zadeh, "Fuzzy sets," *Inf. Control*, vol. 8, no. 3, pp. 338–353, Jun. 1965.



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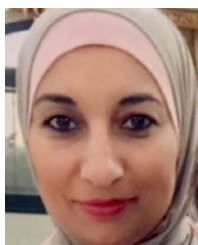
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