Fuzzy logic in suggesting the appropriate university major for students according to their preferences

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***Abstract*—Currently, professional specialization is requested by employers to run high-level business quality. Moreover, it is important for employees for career stability and self-improvement. As a result, universities provide a lot of specialized programs that make it hard for new students to select the most appropriate study program that fits well their qualifications. This work is related to suggesting the most suitable university program for students taking into account a set of criteria such as academic achievement, interests, standard of living, and income. Fuzzy logic is used to build a recommendation system to match university academic programs and the set of students' criteria in order to generate the most suitable programs for students. The experimental test that measures the amount of accuracy of the work is conducted at the end of the work reflects promising results were it emerges a good percentage in the correct selection of majors with respect to the participants.**

***Index Terms*—University Majors, Fuzzy Logic, Recommendation System, Majors-Qualifications Matching.**

I. Introduction

Employees' performance has a direct impact on the suitability of their assigned tasks. It is very important for employers to assign the most suitable tasks to employees in order to maximize the usefulness of their roles [1], [2]. However, job specialization has a direct impact on the assigned career. It makes doing tasks easier, more professional, and able to make critical decisions for the future of organizations.

On the other side, universities used to offer special academic programs in order to graduate specialized students able to steer establishments correctly [3]. However, selecting the right university program is not an easy task for the students of the final elementary level. Several criteria items have to be taken into account: (1) quality of the program, (2) cost of education, (3) access to housing services, (4) safety, (5) social activities, (6) location and climate, and (7) the most important factor is the suitability of the program syllabus with the students' capabilities [4], [5].

The selection of inappropriate academic programs has negative impacts on both students' personalities and their academic achievements. This leads to more costs, useless efforts, and a waste of study time. Frustration, fuzziness, and feeling uncomfortable are considered a set of negative impacts with respect to students studying unsuitable programs [6].

The collaboration between university programs and industry is considered one of the modern methods of learning these days [7], [8]. Content-based learning, project-based learning, and learning by real problems are all samples of teaching techniques used in universities in order to increase the collaboration with industry and to face students with real-life problems as a step to put them in real circumstances as they are employees. The output of this technique is to graduate better-trained students able to face real-life problems that make the fresh graduates able to enroll in practical life easier and stronger. However, these fruitful outputs will not be available with the selection of inappropriate academic programs.

This work is related to implementing a fuzzy logic-based recommendation system to suggest the most suitable university programs (ranked list) for high-level school students taking into account several variables: (1) students' scientific concerns, (2) students' standard of living, (3) the cost of the academic program, and (4) the closeness of universities to students' addresses. These 4 variables are determined according to a questionnaire that prepared and filled by a set of high school students in order to investigate the factors that direct the choices of university majors. After generating the list of ranked majors, the system (From now and on, the words *System* and *Tool* will be used exchangeably) excludes those that do not fit the student GPA.

The rest of this paper is organized as follows: Related work is presented in Section II. The proposed system architecture is discussed in detail in Section III. Section IV describes the implemented fuzzy system used as a recommendation system in the work. The experimental tests are illustrated and discussed in Section V, whereas, Section VI concludes this paper.

II. Related Work

Since choosing an appropriate college major can be critical and confusing in every student's life, several mechanisms and case studies have been proposed to advise and guide the

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student in what kind of career he wants to pursue, and on the other side to bridge the gap between universities and industry in different perspectives [9].

One of these mechanisms reports on a designerly approach to overcoming barriers to university-industry collaboration. The approach is combined with strategic, tactic, and operational dimensions. It builds on three corresponding mechanisms: a tool to facilitate strategic understanding, workshops to facilitate tactical co-creation, and prototyping to facilitate operational ideation [10].

In addition, there are some studies that have addressed the factors of the choice of a college major. The work published in [11] has analyzed the extent to which the choice of a college major depends on the student's expected earnings in that major. Authors of the work have distinguished three parts to expected earnings: the perceived probability of success or perceived ability and effort needed to complete with success the concentration is chosen, the (expected) earnings after graduation, and the earnings alternative if the student fails to complete a college program.

Various researchers have proposed recommendation systems as techniques to deal with large and complex information spaces to filter searching results and enhance the directed contents of information for users. This leads to providing a personalized view of information and prioritizing items likely to be of interest to users. Recommendation systems researchers have incorporated a wide variety of artificial intelligence techniques including machine learning, data mining, user modeling, case-based reasoning, and constraint satisfaction, among others. Moreover, Personalized recommendations are an important part of many online applications [12].

Fuzzy-based recommendation systems are famous today and were embedded in a lot of decision support systems to enhance the mapping between two sets of data [13]. One of these disciplines is the university's major suggestions to students. Through this, students are able to get some help from an expert system to facilitate the selection of their most suitable majors and hence their future careers. The study published in [14] focused on designing a Fuzzy Recommendation System (FRS) that aided in students' decision in choosing their university major. Additionally, a cluster-based preferences technique was implemented to obtain the student's preferred majors, using distance measurement.

The work published in [15] has proposed a career path recommendation mechanism for students in engineering streams after the 12th-grade examination. More specifically, that system utilizes multiple measurements from a three-dimensional model, that is, Preference generation, fuzzy logic-based career selection, and influence-based trust measuring. By integrating these measurements with the relative weighted set generated using Analysis Hierarchical Process (AHP) decision system, the desired score of student-related to each career-oriented engineering stream is computed.

Our contribution in this work takes into account a set of factors that the previous work mentioned earlier did not take into their account. This work is different from the previous ones by considering a set of confusing factors that might lead to enrolling in an unsuitable university major if not studied well.

III. System Architecture

In this section, we provide an illustrative overview of the tool and its structure, showing its main components and their functions. The client/server architecture tool is composed of a set of tiers: (1) Client Side: to deal with user interactions, (2) Server Side: represented in the code to implement the Fuzzy Engine that has direct contact with the (3) Database. Figure 1 depicts the set of system tiers.

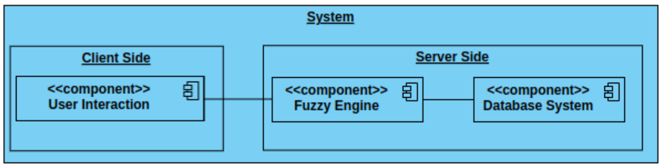

Fig. 1. The set of system tiers.

A. *Client Side*

This tier represents the tool interface with users. It is composed of a set of client-side scripts to deal with the interactivity between the users and the system. This tier is based on the request-reply protocol of interactivity where the users request services provided by the tool. This tier is programmed by *JavaScript* where *AJAX* is used to conduct the communication between this client-side and the server-side of the tool.

Figure 2 reflects the functionality that takes place when requesting a list of ranked majors according to some student data. The activity starts when the student executes the method *suggestMajor(data)* on the *AJAX* object. The parameterized *data* is the data related to the students in terms of their scientific levels and financial situations. The object *AJAX* as a result executes the method *computeRanks(data)* on the object *Fuzzy Engine* that in turn loads the list of all universities' majors from the *database* object by calling the method *loadMajors* that loads the list of majors in *Majors[]* array. According to this, the member method *generateRanks(Majors, data)* of the object *Fuzzy Engine* is executed to apply the recommendation system facilities to generate a ranked list of majors stored in the array *Ranks[]* that returned back to the students in order to choose the best majors that fit their facilities after taking their GPAs into account.

B. *Fuzzy Engine*

This tier is the most important part of the system. It represents its functionality by executing a set of server-side

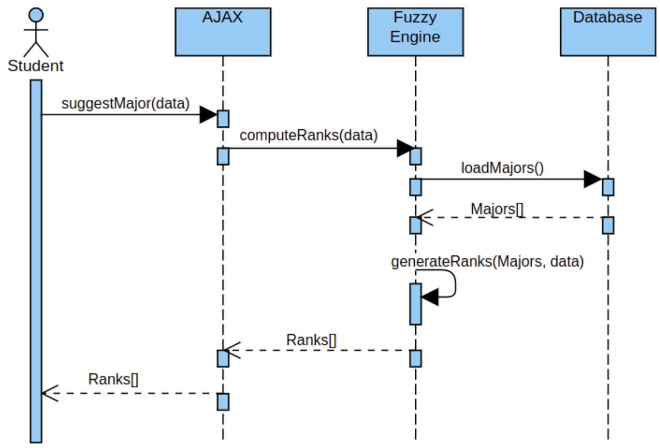

Fig. 2. Sequence diagram for requesting ranks of majors.

scripting language (PHP) codes. This part of the system is the connectivity between the client side and the database parts of the system. It is responsible for answering the clients' requests by extracting their related data from the database part and sending the formatted replies to the clients. This part of the tool will be discussed in detail in the later sections.

C. Database

This part of the system is composed of a set of database entities to save the data that the Fuzzy Engine works on. The data about students, universities, and specializations are all stored in this part. Figure 3 represents the Entity Relationship diagram of the system. It is composed of a set of entities and their corresponding attributes. The *Major* entity is used to store data about the specializations provided by the universities that are stored in the *university* entity. The *Location* entity has a one-to-one relationship between both entities: *University* and *Client*. This entity will be used to compute the distances between universities and students' residences.

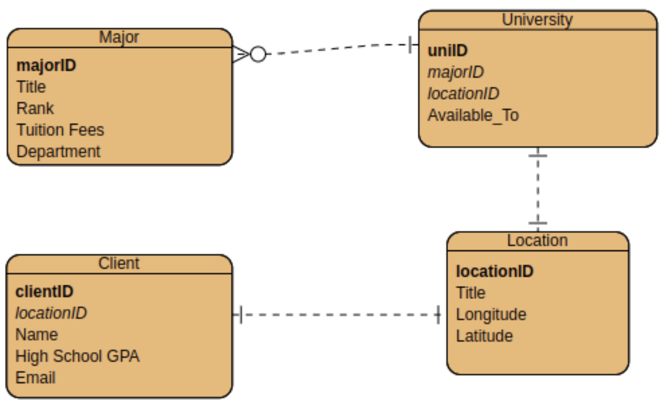

Fig. 3. Entity-Relationship Diagram.

IV. Fuzzy Based Recommendation System

This part of the tool is considered a recommendation system where the students are informed by the most suitable universities' majors according to a set of students' qualifications such as their scientific concerns, standards of living, the majors' tuition fees, and the closeness of universities to students locations, as well as the students' GPAs. In the following section, we are describing the implemented Fuzzy system in detail.

A. Fuzzy Variables

The fuzzy-based recommendation system implemented in this work is based on two Fuzzy Variables: the **Student** and the **University**. The **Student** fuzzy variable is determined according to two criteria: *Student Financial Level* and *Student Scientific Concerns*. However, these criteria are determined by collecting a set of data gathered from a sample of students using a prepared questionnaire where the students are asked a set of questions in order to determine their amount of scientific concerns. The questionnaire is composed of well-studied questions prepared to collect precise information about the students and the university majors and is filled by 978 participants. 5 Palestinian universities were included in the study with 10 majors each. The included majors are : *Civil Engineering*, *Mechanical Engineering*, *Chemical Engineering*, *Physics*, *Mathematics*, *Biology*, *Medicine*, *Pharmacy*, *Computer Science* and finally, *Networks & information security*. Although the included majors are scientifically disciplined, the conducted system can include other disciplines. The questionnaire is composed of a set of sections represented in:

1) University Major: the suitability of majors is scaled to 5 degrees, 1 is the worst, and 5 is the best.
2) Student Financial Level: it is scaled up to 3 categories: 1 for poor students, 2 for intermediate, and 3 for rich.

To quantify both the scientific concerns and the financial situation, we summed up the values of scales for students at the end of the questionnaire filling process. Obviously, the scientific concerns in the worst cases sum up to 5 and in the best cases to 25.

The *Student* fuzzy variable is then computed by a special formula where the major and living standard are given the weights 0.6 and 0.4 respectively (These weights are determined according to a study conducted on a set of students), just to emphasize the scientific levels of students. Formula 1 illustrates the computation of the *Student* fuzzy variable where *sciCon* represents the students' scientific concerns and the *fState* is related to their financial situations. For example,if the sum of values for the scientific concern is 17 and the financial status is 2, then the amount of *Student* fuzzy value is:$17 \times 0.6 + 2 \times 0.4 = 11$. According to this, the upper value of *Student* fuzzy variable is $25 \times 0.6 + 3 \times 0.4 = 16.2$ and the lower value is $5 \times 0.6 + 1 \times 0.4 = 4.2$ and by considering these two limits, we divided this range into 5 fuzzy sets with the intervals: $0.0 - 6.6$ (Very Bad), $3.4 - 9.8$ (Bad), $6.6 - 13.0$ (Good), $9.8 - 16.2$ (Very Good), > 13.0 (Excellent) taking into account the interval size to be 3.2 as shown in Figure 4. However, fixing the number of fuzzy intervals to be 5 is just for testing purposes for this work. However, future work will include an elbow algorithm (auto-categorization technique) to study data to suggest the best number of fuzzy intervals.

$$Student = sciCon \times 0.6 + fState \times 0.4 \tag{1}$$

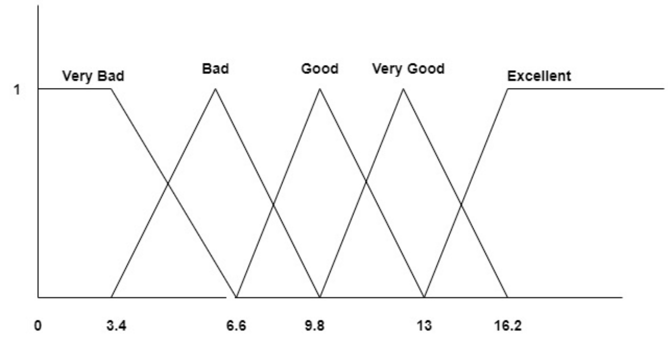

Fig. 4. *Student* fuzzy intervals.

The second fuzzy variable is related to the included universities with their offered majors. The *University* fuzzy variable is computed from three sets of data: Universities locations, Programs tuition fees, and their ranks. As we did in the *Student* fuzzy variable, we conducted a special equation to include these three criteria. Formula 2 depicts this relation where the three variables reflect the mentioned criteria elements. Of course, the distance is computed between the student's residences and the universities depending on their locations that are taken from the database. Again, the weights used in the equation are determined by a study conducted on a set of students.

$$University = Rank \times 0.5 + Fees \times 0.2 + Distance \times 0.3 \tag{2}$$

To quantify the amounts of *Rank*, *Fees* and *Distance*, we prepared a special questionnaire where each criteria is scaled to suitable values. The *Rank* is scaled into a value from 1 (worst) to 5 (best), the *Fees* is scaled into a value from 1 (cheap) to 3 (expensive), while the distance is scaled into 1 (far) to 3 (close). For example,if the university rank is 3, the financial status is 2, and the distance is 2 then the amount of *University* fuzzy value is: $3 \times 0.5 + 2 \times 0.2 + 2 \times 0.3 = 2.5$. According to this, the upper value of *University* is $5 \times 0.5 + 3 \times 0.2 + 3 * 0.3 = 4.5$ and the lower value is $1 \times 0.5 + 1 \times 0.2 + 1 \times 0.3 = 1.0$ and by considering these two limits, we divided this range into 5 fuzzy sets with the intervals: $0.0 - 1.8$ (Very Bad), $1.0 - 2.6$ (Bad), $1.8 - 3.4$ (Good), $2.6 - 4.2$ (Very Good), > 3.4 (Excellent) taking into account the interval size to be 1.6 as shown in Figure 5.

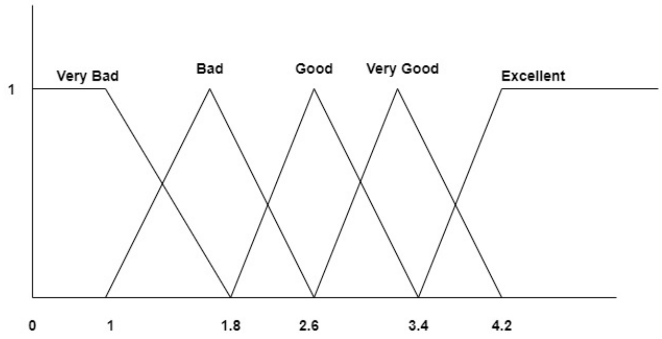

Fig. 5. *University* fuzzy intervals.

Table I represents the possible values of combining the two fuzzy variables **Student** and **University** where the combination of them provides a different linguistic value. For example: if **Student** is *Good* and **University** is *Very Good*, the output will be **Very Good**. Again, the determination of these values is done according to a survey with a set of participants. However, the fuzzification and defuzzification processes depend on this table in order to generate ranks of University Majors for students by applying the *And* operator on fuzzy sets. Figure 6 depicts the values of the result fuzzy variable. The values from 1 to 7 appear in the *x-axis* of the figure and are used as weights in the defuzzification process.

	Very Bad	**Bad**	**Good**	**Very Good**	**Excellent**
Very Bad	Very Bad	Bad	Accepted	Moderate	Good
Bad	Bad	Accepted	Moderate	Good	Very Good
Good	Accepted	Moderate	Good	Very Good	Excellent
Very Good	Moderate	Good	Very Good	Very Good	Excellent
Excellent	Accepted	Good	Very Good	Excellent	Excellent

TABLE I
THE COMBINATION OF THE TWO FUZZY VARIABLES: *Student* AND *University*.

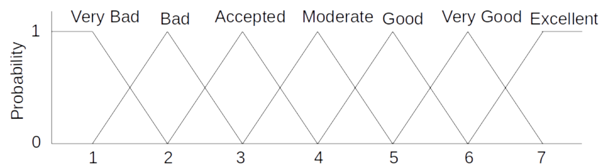

Fig. 6. Intervals of the result Fuzzy Variable.

B. Defuzzification Process

To obtain final crisp value for both *Student* and *University*, a defuzzification process is executed depending on the **Centre of Gravity for Singletons** formula:

$$CrispValue = \frac{\sum_{i=1}^{n} \mu_i \times o_i}{\sum_{i=1}^{n} \mu_i} \tag{3}$$

where o_i is the corresponding value for the output variable of index i, μ_i is the membership function after accumulation for that variable, and n is the number of variables. The reason we rely on **Centre of Gravity for Singletons** in our computations is related to its simplicity and clearness [16].

Figure 7 reflects the major steps of the Fuzzification-Defuzzification process.

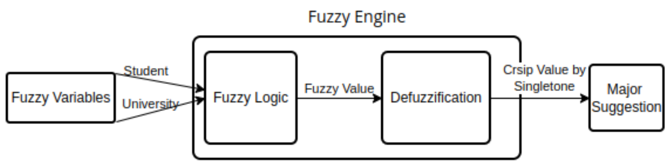

Fig. 7. Fuzzification-Defuzzification procss.

C. Illustrative Example

To illustrate how the fuzzy logic recommendation technique is used in this work, we will go on with an example illustrating the different calculations to generate a ranked list of majors based on some suggested numbers for both of the linguistic variables. A student S with a scientific value 22 and a financial situation 2 needs to use the tool to search for suitable majors (of course, these values are accumulated after the student fills out a questionnaire). Suppose two majors $M1$ with rank value 4, tuition fees value 2 and location value is 3, $M2$ with rank 5, tuition fees 2 and location 1. In this case, the rank of the two majors with respect to the student is calculated by computing the corresponding fuzzy values of both *Student* and *University*.

For *Student* it is $22 \times 0.6 + 2 \times 0.4$ gives the value 14 and for *University* with $M1$ is $4 \times 0.5 + 2 \times 0.2 + 3 \times 0.3$ gives the values 3.3 and for $M2$ is $5 \times 0.5 + 2 \times 0.2 + 1 \times 0.1$ gives the value 3.

For $M1$:

- For Student:
  - $\mu(Excellent) = \frac{14-13}{16.2-13} = 0.3125$
  - $\mu(VeryGood) = \frac{16.2-14}{16.2-13} = 0.6875$
- For University :
  - $\mu(Good) = \frac{3.3-2.6}{3.4-2.6} = 0.875$
  - $\mu(VeryGood) = \frac{3.4-3.3}{3.4-2.6} = 0.125$

Now, from Table I, we can compute the following:

- if Excellent and Good then Very Good, so $0.3125 \cap 0.857 = min(0.3125, 0.857) = 0.3125$
- if Excellent and Very Good then Excellent, so $0.3125 \cap 0.125 = min(0.3125, 0.125) = 0.125$
- if Very Good and Good then Very Good, so $0.6875 \cap 0.875 = min(0.6875, 0.875) = 0.6875$
- if Very Good and Very Good then Very Good, so $0.6875 \cap 0.125 = min(0.6875, 0.125) = 0.125$

As a result, we have:

- $\mu(VeryGood) = max(0.3125, 0.6875, 0.125) = 0.6875$
- $\mu(Excellent) = 0.125$

Depending on the intervals' values in Figure I, we can compute $M1$ rank: $M1 = \frac{6*0.6875+7*0.125}{0.6875+0.125} = 6.154$ represented by the shaded area appears in Figure 8 below.

Fig. 8. Intervals of the result Fuzzy Variable for $M1$.

For $M2$:

- For Student:
  - $\mu(Excellent) = \frac{14-13}{16.2-13} = 0.3125$
  - $\mu(VeryGood) = \frac{16.2-14}{16.2-13} = 0.6875$
- For University :
  - $\mu(Good) = \frac{3-2.6}{3.4-2.6} = 0.5$
  - $\mu(VeryGood) = \frac{3.4-3}{3.4-2.6} = 0.5$

Now, from Table I, we can compute the following:

- if Excellent and Good then Very Good, so $0.3125 \cap 0.5 = min(0.3125, 0.5) = 0.3125$
- if Excellent and Very Good then Excellent, so $0.3125 \cap 0.5 = min(0.3125, 0.5) = 0.3125$
- if Very Good and Good then Very Good, so $0.6875 \cap 0.5 = min(0.6875, 0.5) = 0.5$
- if Very Good and Very Good then Very Good, so $0.6875 \cap 0.5 = min(0.6875, 0.5) = 0.5$

As a result, we have:

- $\mu(VeryGood) = max(0.3125, 0.5, 0.5) = 0.5$
- $\mu(Excellent) = 0.3125$

Depending on the intervals' values in Figure I, we can compute $M2$ rank: $M2 = \frac{6*0.5+7*0.3125}{0.5+0.3125} = 6.38$ represented by the shaded area appears in Figure 9 below.

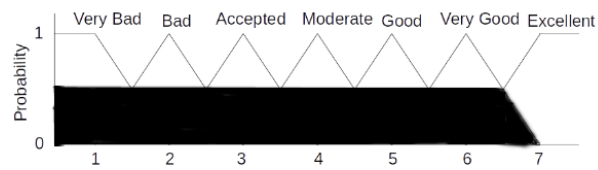

Fig. 9. Intervals of the result Fuzzy Variable for $M2$.

Since the value of $M2$ is bigger than the value of $M1$, $M2$ comes before $M1$ in the ranking of the two majors, and this means that the system recommends the student with the major $M2$ for the given university.

At the end of the calculations, each major's acceptance average in each university is compared with the student's average to determine if that specific major in this specific university is taken into account or will be excluded. The following simple pseudocode represents the filtering process.

```
rankedList[] = new List();
for(major in majors[]){
    if(studentAverage >= major.acceptanceAverage)
        rankedList.include(major);
}
```

As a result, the top 3 majors are displayed to the students to help them in selecting the most suitable major.

V. Experimental Tests

In order to test the implemented work and to be sure of the efficiency of the tool, we executed a comprehensive test where 10 participants (already enrolled in a bachelor's degree) tried the tool in order to see the amount of similarity between the suggested majors and their real ones [17]. The participants filled out the prepared forms and fed the tool with their financial situation and their distances from the university and asked the tool to suggest the best majors that fit their qualifications. The tool generated a ranked list of suggested majors for each participant. Table II reflects the results of the experiment in which the **suggested** column lists a ranked list of the top 3 related majors for each participant and the **Real** column lists the real majors of the participants. In order to quantify the amount of tool efficiency, we count the number of hits against the number of fails of the data that appear in the table for both majors and universities regardless of the order of the ranked list. For example, participant number 1 has been suggested **Pharmacy** and **University 1** by the tool, and in real, s/he studies Pharmacy in University 1, this counts 2 hits. Applying this to all participants, we get 6 hits against 4 fails (all in majors). Regardless of the number of fails in majors we got, we can see that there are some similarities between the suggested majors and the real ones. For example, participant 2 has been suggested to study networks, and s/he studies computer science, both majors are related to information technology. Participant 4 has been suggested to study Biology and s/he studies Medical Labs. And Finally, participant 5 has been suggested with Biology and s/he studies Medicine. The only real failure is related to participant 3 because s/he studies computer engineering and has been suggested with 3 different majors. However, even this can be related somehow, because both the list of suggested and the real studied majors are all grouped in scientific majors. If we assign a half point for the cases in which the suggested majors and the real ones are much related, we have 7.5 hits against 2.5 fails and this gives the amount of efficiency equals to 75%.

The following is a list of sample questions filed by the participants:

1) In which university you are studying now? or graduated?
2) What are the criteria that drive you to chose the university? (Average acceptance, Quality of education, Tuition fees, distance, others).
3) What is your current major?
4) What are the criteria of your major selection? (Employment chance, Family suggestion, upon your high school GPA, Your desire, others).

TABLE II
A LIST OF SUGGESTED MAJORS VS. REAL ONES.

#	Suggested		Real	
	Major	**University**	**Major**	**University**
1	Physics	University 1	Pharmacy	University 1
	Biology	University 1		
	Pharmacy	University 1		
2	Biology	University 1	Computer Science	University 1
	Physics	University 1		
	Networks	University 1		
3	Physics	University 1	Computer Engineering	University 2
	Pharmacy	University 1		
	Civil Engineering	University 2		
4	Biology	University 1	Medical Labs	University 1
	Pharmacy	University 1		
	Physics	University 1		
5	Biology	University 1	Medicine	University 1
	Physics	University 1		
	Pharmacy	University 1		

5) Are you satisfied with your major?
6) In your opinion, what the best university in Palestine offers your Major?
7) Additional notes?

VI. Conclusion

Selecting the most suitable major is very important in students' lives since this reflects positively on their personalities and maximizes their potential in their career lives. This of course has a direct impact on societies and decreases the number of people unemployed. This work is related to implementing a tool to suggest the best majors for high school students taking into account their potential, financial situations, amount of majors' fees, the closeness of universities, and the ranks of university majors all converted into two fuzzy labels: *Student* and *University*. An experimental test is conducted in order to measure the amount of suitability of using the tool where the outcomes indicate the right choice of participants majors in which this reflects a future improvements in their careers.

For future works, additional vectors will be added to the Fuzzy engine like the possibility of employment of some majors and the average amount of income for majors as well as including more disciplines rather than the scientific ones.

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