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Designing an automated matching model to enhance recruitment process

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ABSTRACT

Detecting qualified candidates for a vacant position is a difficult task, especially when there are numerous applicants. This delays team development in finding the appropriate individual at the right moment. Adopting a well-structured selection process will create opportunities for new aspects and ideas. In this paper, the matching job applicant (MJA) model is developed to assist all parties, the employers and the employees simultaneously by providing a fair, transparent unbiased solution constructed by using a mathematical machine. This provides a clear justification in the decision-making process in addition to advising the applicants with the most suitable positions that fits their qualifications.

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1. INTRODUCTION

Due to the rapid growth in economics, the convoluted employment market condition in many nations around the world and the employees' growing geographic freedom has increased the competition between public and private companies in electing qualified employees [1], [2]. As a consequence of this status, searching for the innate ability, talent, skills, interest and experience is not an easy task [3]. This refers to the assumption that the candidates have the knowledge and skills to contribute to the job quickly and smartly. Therefore, there is an urgent need to activate internships, job shadowing opportunities, and even some full or part-time jobs.

The recruitment as defined by Gamage [4] is the process of finding qualified employment candidates for an organization while remaining cost-effective. However, the selection process involves choosing the most qualified candidate from a pool of applications by using specific tools to fill a job vacancy as mentioned by Ofori and Aryeetey [5]. Employers improve the hiring process by using automated matching systems that match the most qualified candidate for open positions through CV processing, search, and retrieval. Although matching technology has advanced recently, the business has faced strong resistance from the public sector

and security-conscious organizations that depend on hiring fresh/expert personnel to maintain a diversity of expertise [6].

Technology has made enormous advances in the four stages of the recruitment and selection process which has a valuable impact in the various human resource (HR) roles [7]. Developing mathematical methods for enhancing recruitment processes is crucial in modern societies [8]. Companies are using an automated matching system to enhance the recruitment process by using CV processing search and retrieval to match the best applicant for the vacant position [9]. The automated hiring procedure targets to accelerate and enrich the process of selecting the best candidate applicant for a job position. The recruitment process comprises of several tasks, including JD/Resume matching, interview scheduling, and review/interview panel construction, which are automated with the use of advanced technology. Enforcing automation in the recruitment process makes it more inclusive, efficient, and economical [10]. The automated hiring process has been examined in several research studies including the application of knowledge bases [11], artificial intelligence [12], and machine learning [13] to improve candidate selection quality and the matching process. These studies suggested developing prototype systems and implementing algorithms that offer better approaches and recommendations when compared to the classical manual methods.

In order to provide a fair, transparent and unbiased solution that helps the company and the applicant simultaneously, we designed and developed the matching job applicant (MJA) model. This model utilizes the computational machine entitled matching job applicant candidate (MJAC). The latter serves both parties smartly in a fair and precise way. It facilitates the company to find the top k~candidates for its posted jobs in the recruitment process. Consequently, this will eliminate the burden of searching and filtering appropriate candidates based on a set of criteria determined by the employers. At the same time, this method notifies the applicant with the most suitable jobs that fits their qualifications.

The recruitment process consists of multiple steps starting by identifying the need to fill the vacant position in the company, attracting and assessing the best candidates, and finally hiring the best individuals for a job opportunity [14], [15]. Automating the recruitment process describes the use of technology to optimize and expedite the hiring process steps to support the human resource operations. Designing an automated process for recruitment was presented by Silva *et al.* [16] to improve and assist the organization's hiring procedure for new staff members. A number of recruitment-related tasks, including posting jobs [17], screening candidates [18], setting up interviews [19], and organizing application data [20], are automated. The automated system for handling the recruitment process targeted to decrease manual labor, increase productivity, and guarantee a better coordinated and successful hiring procedure. The matching process is the major component in the recruitment process which guarantees choosing the best candidate for the vacant position in the company. Automated the matching process has been extensively investigated in the literature from different perspectives [21]-[24]. This section reviews and summarizes recent works between 2014 and 2024 in this area.

Creating an integrated view of the application processing problem by taking into account two of the most significant components of the problem: The design of the review/interview panel and the scheduling of interviews was presented by Sharma *et al.* [25]. Geetha and Reddy [26] highlighted eight different ways of applying AI to the hiring procedure by providing an understanding of its impacts, difficulties and limitations. It is worth mentioning that, the findings in this conceptual study might not apply properly to all businesses, or sizes of organizations. Also, the adoption and efficiency of AI in the recruiting process are affected by factors such as cultural variations, industry attributes' difficulties, and regulatory frameworks. In order to save time and effort for professionals handling the proper manpower requirement, Umachandran [27] provided a survey of current and pertinent research on human resource recruiting by using AI.

Based on the job description provided by the company, an automated machine learning (ML) model was shown by Roy *et al.* [28] suggests a qualified candidate's resume to HR. The suggested model consists of two steps. First of all, resumes are organized into various classes. Secondly and more importantly, candidate resumes are suggested based on its closeness to the job description. Unfortunately, there are many challenges in this model: Inability of handling different kinds of the resumes' formats and the possibility of losing the valuable data of candidate because of the summarization process. An interesting study showed how ontologies and knowledge bases can be integrated with contemporary language models, which are based on transformers, to improve the JD/Resume matching process was presented by Barrak *et al.* [29]. This suggested architecture is known to be traceable, equitable, and comprehensible. Maheshwary and Misra [30] suggested training the Siamese network to assess how well a resume fits a job description by utilizing the textual similarity. While Siamese networks learn embeddings in a high-dimensional space and compute the matching value between job class and the resume, it is difficult to attribute the decision-making process to particular features or rules and it might not provide an explanation for why a certain value was given. Joseph *et al.* [31] described the use of deep learning and natural language processing (NLP) to build an autonomous system for technical interviews during college recruitment. During the interview process, candidates are

asked to complete all online questions by an autonomous interviewer, and their performance is evaluated at the conclusion.

In this paper, we are designing the MJA model that highlights the best k~candidates for the posted job in the recruitment process by utilizing computational machine MJAC which provides the justification to attribute the decision-making process from the company side. Also, it advises the applicant for a set of the most suitable jobs fits his/her qualifications. This paper is organized as follows: the proposed MJA model is presented in section 2. Section 3 illustrated results and discussion. Conclusion was clarified in section 4.

2. THE PROPOSED MJA MODEL

This section explains intensively the MJA model which provides a fair, transparent and unbiased solution that helps the company and the applicant simultaneously. It consists of three major parts: company, applicant and the mathematical machine entitled MJAC as shown in Figure 1. The company should positively feed the model with a list of required skills and qualifications for a specific posted job. Also, the applicant provides the model with his/her proficiency and skills as required. The major component in this model is MJAC method for searching and filtering the major functionalities that assists companies to obtain the appropriate candidates based on set of criteria and help candidates to find the vacant position that suitable for their interests and qualifications as depicted in Figure 2. This method provides a chance for companies to access a number of candidates with massive diversity from different educational environments, skills and experience. Simultaneously, it provides the applicant with a list of the proper posted job vacancies. This helps in reducing the actual cost and time compared with the recruitment process.

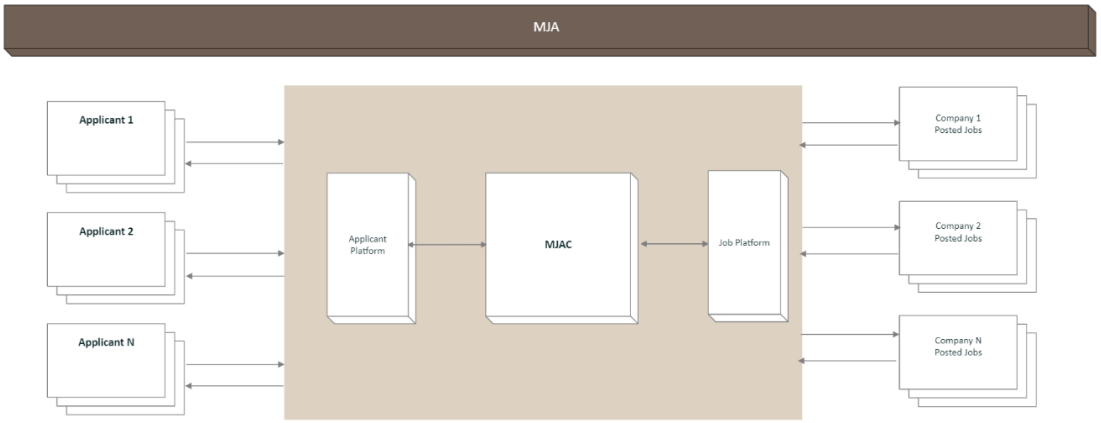

Figure 1. MJA model

The computational model of MJAC is represented as follows:

MJAC = (S_J, S_A, δ, γ), where:

- S_J= {J_1, J_2, ……., J_n}, is the set with cardinality equals n of job tuples. Each job tuple shows the most important required skills specified by the company with size equals *k+1*. Each job (J_i) can be viewed as a data vector:

$$J_i^T = [j_p, j_{i1}, j_{i2}, j_{i3}, \dots\dots\dots\dots\dots\dots\dots j_{ik}],$$

where j_p is a surrogate key that identifies the posted job and j_{it} specifies a binary value of the job j_i in the t^{th} specifications required by the company:

$$j_{it} = \begin{cases} 1, & the\ specification\ is\ required\ by\ the\ comapny \\ 0, & the\ specification\ is\ not\ required\ by\ the\ comapny^* \end{cases}$$

- S_A= {A_1, A_2, …, A_m}, is set with cardinality equals m of applicant tuples. Each applicant tuples represents the applicant specifications with size equals *k+1* that is required by the company. Each applicant A_i can be viewed as a data vector:

$$A_i^T = [a_p, a_{i1}, a_{i2}, a_{i3}, \dots\dots\dots\dots\dots\dots\dots a_{ik}],$$

where a_p is a surrogate key that defines the applicant and a_{it} specifies categorical or numerical value of the i^{th} applicant with a specific qualification t.

– $\delta : S_J \times S_A \rightarrow Q$, is a transition function of the cartesian product of S_J and S_A mapped to Q. Q is a set of ordered pair where the first position is J_i^T and the second position is A_i^T as shown below.

$$Q = \begin{Bmatrix} (J_1^T, A_1^T), (J_1^T, A_2^T), \ldots\ldots (J_1^T, A_m^T) \\ (J_2^T, A_1^T), (J_2^T, A_2^T), \ldots\ldots (J_2^T, A_m^T) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ (J_n^T, A_1^T), (J_n^T, A_2^T), \ldots\ldots\ldots, (J_n^T, A_m^T) \end{Bmatrix}$$

The most important step which plays a predominant role in matching process is transforming Q to JAC (Job Applicant Candidate) matrix. It represents the candidate applicants for a specific job with their corresponding computed proficiency weights ω. The JAC is represented as:

$$JAC = [j_p, a_p, \omega]$$

where $j_p$is a job surrogate key, $a_p$is the applicant surrogate key and ω is a computed proficiency weight that estimates the fitness of the applicant a_p to fit the specific job requirements presented as j_p.

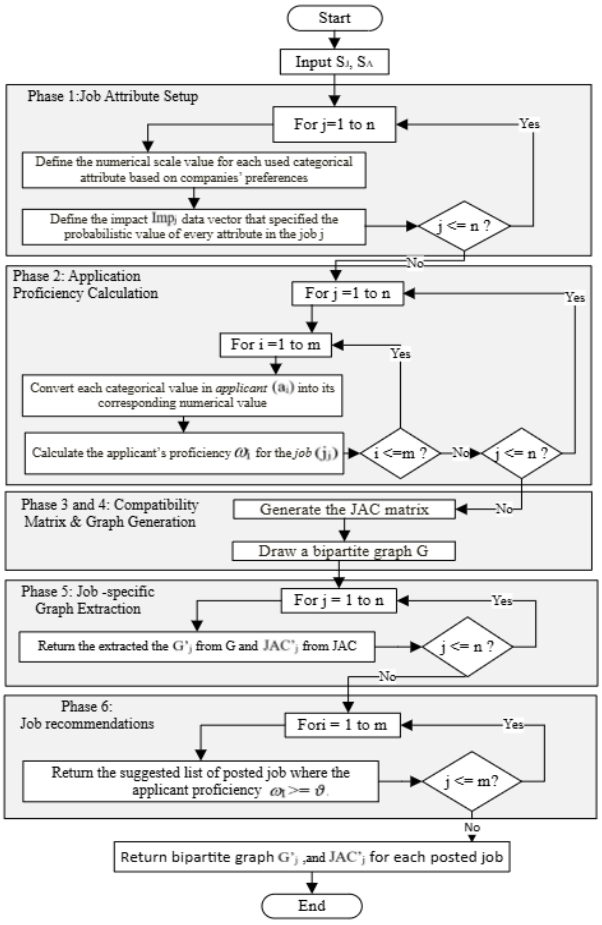

Figure 2. The flowchart of the MJAC method

– $\gamma = \{Imp_1, Imp_2, \ldots\ldots\ldots Imp_n\}$, is the set of tuples with cardinality equals n. It represents the impact of each job qualifications in the recruitment process as specified by the company. Each Imp_j for a job position j can be viewed as a data vector

$$Imp_j^T = [j_p, I_{j1}, I_{j2}, I_{j3}, \dots\dots\dots\dots\dots\dots\dots I_{jk}],$$

where I_{jt} specifies the impact of the t^{th} qualifications for the j^{th} job in the selection process. Taking in the consideration that the summation of all the impacts' values of the qualifications for a certain job is equal to 1, as follows:

$$\sum_{t=1}^{k} I_{jt} = 1$$

It is important to note that any certain job specifications not required by the company in the selection process, its corresponding impact value should be equal to zero. The stochasticity of the impacts deterministically shapes the eligibility of the applicant to the corresponding job. It computes the fitness value of the applicant a_i to the job j by assigning a stochastic computed value of proficiency (ω):

$$\omega_{ij} = \sum_{t=1}^{k} I_{jt}^T * a_{it}$$

The method of generating the MJAC is presented in Algorithm 1. It receives two input parameters: The set of posted jobs, S_J and the set of applicants, S_A. To begin with, for every posted job j the numerical scale value for each used categorical attribute has to be defined based on the company preferences as shown in Line 1.1. Also, defining the impact value for every attribute helps in estimating the fitness value of this attribute in the posted job as shown in Line 1.2. In other words, the impact data vector for the posted job represents the probabilistic value which reflects the importance of the required attribute in estimating the influence of the specific skill in the job j (every unrequired attribute assigns to value zero). In Line 2, applying the cartesian product by invoking nested loops of jobs and applicants used to calculate the proficiency value ω for every single applicant utilizing this model for every single posted job j. Generating the JAC matrix is nothing more than storing the surrogate key of the posted job j_p and surrogate key of the applicant a_p with his/her corresponding proficiency value ω for that job as illustrated in Line 3.

The most attractive feature in this method is shown in Line 4 where the model generates the bipartite graph, *G*, that presents all relations between the candidates' qualifications and the companies' posted jobs. Accordingly, this saves the time and resources by providing the vital information for both parties by connecting the vacant position with every employee's credential. At the end, this model has the ability to extract the subgraph G' from the bipartite graph G which reflects the proficiency values for all employees for every posted job in this company. It is worth mentioning that, the company may specify the top k~candidates' employee for the posted jobs for any k value greater or equal to 1. Additionally, we cannot deny the ability of the model to return the suggested list of posted job where the applicant proficiency ω_I is greater than or equal to a certain threshold value (ϑ) which is equal to the average of all the applicants' proficiency for this specific posted job as shown in Line 6. Finally, this method provides real recommendations on how to improve the existing system to better meet the demands of the employer as well as keeping in fulfillment with the fairness of selection. Simultaneously, it provides the applicant with a list of suggested jobs that matches his/her proficiency. These amazing services are implemented in a polynomial degree time complexity θ(n*m), where n is the number of posted jobs and m is the number of applicants.

Algorithm 1. MJAC method

```
Input: SJ: The set of posted jobs, |SJ|=n.
         SA: The set of applicants, |SA|=m.
Output: Bipartite graph G'j, and JAC'j for each posted job.
1.  For j=1,……..n do
    1.1. Define the numerical scale value for each used categorical attribute based on
         companies' preferences.
    1.2. Define the impact Impj data vector that specified the probabilistic value of every
         attribute in the job j.
2.  For j=1,……..n do
    2.1. For i=1…….m do
        2.1.1. Convert each categorical value in applicant (ai) into its corresponding
               numerical value.
        2.1.2. Calculate the applicant's proficiency ωi for the job (jj).
3.  Generate the JAC matrix.
4.  Draw a bipartite graph G.
5.  For j=1,…….n do
    5.1. Return the extracted the G'j from G and JAC'j from JAC.
6.  For i=1,….m do
    6.1. Return the suggested list of posted job where the applicant proficiency ωI >= ϑ.
```

3. RESULTS AND DISCUSSION

This study investigated the development of an automated MJA model to improve the recruitment process. While previous researches have studied different methodologies of embedding artificial intelligence, machine learning, and knowledge-based systems in recruitment, none has explicitly addressed the integration of a computational matching machine (MJAC) that combines candidate qualification weighting, bipartite graph construction, and proficiency scoring in a unified decision-making framework. This gap emphasizes the need for a more visible, explainable, and statistically grounded mathematical approach to assist both employers and applicants in the selection process.

Our findings revealed that the computed proficiency score between the predefined set of job criteria and candidate qualifications is highly correlated with the impact weight assigned by employers to specific job criterion such as experience, GPA, and certifications. When compared to the classical selection approaches, the suggested MJA model consistently found the top-matched applications. Furthermore, the usage of a bipartite graph visualization does not only improve understanding of applicant-job alignment but also allows well-versed decision making. The system's capacity to recommend jobs to candidates with proficiency values higher than the average threshold was beneficial in improving applicant-job matching precision and overall recruitment efficiency.

Different studies tackled the importance of automating the recruitment process through different approaches such as artificial intelligence and data driven system. Previous studies [21]-[24], [28]-[30] have indicated the significance of the proficiency score and application job alignment in endorsing the transparency and explainability in the selection process. Most of the commonly used approaches were relying on deep learning embedding or ontological mapping in contrast of the proposed MJAC method which presents a structured framework that integrates impact weighted proficiency scoring with bipartite graph modeling to assure interpretability and decision-making traceability. The electronic job matching platform demonstrates an organized data-driven approach to the recruitment process. Notably, this study reveals a positive correlation between job-matching accuracy and higher degree of alignment between an applicant's qualifications and the job requirements. The proposed method obtains competence-based ranking and structured scoring mechanism contributing to the overall the accessibility and integrity of the selection process.

An electronic platform was created in March 2024 to facilitate the job matching process in Jordan. It consists of two real datasets entitled: jobs and applicants in CSV format. The jobs dataset consists of fifteen attributes that describes the available job vacancies announced by the company. On the other hand, the Applicants dataset comprises of sixteen attributes that describes the specified qualifications filled and submitted by the applicant. There are eleven common attributes in both datasets: Specialty, gender, status, degree, major, university, university ownership, GPA, experience, courses, and certificates. It is worth mentioning that the demographic attributes in both datasets are different. Jobs dataset consists of four demographic attributes: Company name and address to declare the company, in addition to the job title and job description to define the specifications of the posted job. While the applicant dataset consists of five demographic attributes: applicant name, address, nationalID, telephone number and e-mail address. The development of this platform that utilizes the MJA model was carried out on computer with the following specifications: Intel(R) Core(TM) i7-4702HQ @ 2.20GH, 16 GB RAM and Windows 10X64 operating system. This platform utilizes several libraries in Python 3.11 such as (Pandas 2.1.0, NumPy 1.26.0, Matplotlib 3.7.2, Scikit-learn 1.3.0) and network x 3.2.

The company plays a predominate role in creating the posted job. It initiates the four demographic attributes in the *Jobs* dataset. Then it determines the specialty attribute by specifying the sector of the posted job such as: Accounting, management, and information technology. Noted that the selection process starts by filtering all applications based on the value specified in the specialty attribute. After that, the company declares the domain values of every categorical attribute in the common eleven attributes as shown in the values column in Table 1. The company holds the responsibility of scoring every domain value in the categorical attributes to be used in computing the fitness value of the applicant to the posted job.

The essential step is to assign the impact value of every single chosen attribute (in the eleven common attributes) in the selection process as shown in the Impact column in Table 1. This is addressed in the company platform side by checking the contributed attributes in the fitness value by assigning the impact values in the corresponding field presented in Figure 3. It is important to remember invoking the integrity of assuring that the summation of the impact values of the chosen attributes is equal to one. Consequently, the remains unchosen attributes have impact value equal to zero.

The applicant has to correctly fill the requirements skills in the applicant platform by confirming that all provided information is correct and accurate as shown in Figure 4. When the deadline of applying to a certain posted job is reached, the MJAC method will calculate the proficiency value of each applicant to the specific posted job. This is achieved by computing the fitness of each applicant by assigning the stochastic

computed value of his/her proficiency as shown in Figure 5. Moreover, Figure 5 shows the list of all candidates who are satisfied all the requirements and ranked according to their proficiency values. It is worth mentioning that, the results are visualized as a bipartite graph to simplify the selection process of the top k~candidates as determined by the company for all posted job as shown in Figure 6. Figure 7 shows the applicant navigation screen which presents the list of suggested posted jobs that his/her qualifications equal or above the average of the proficiency values for all applicants. The applicants have the choice to choose to accept or decline every suggested posted job. By choosing the accept button, the qualifications of the applicant will be confirmed in the company side. While choosing the decline button will remove the applicant's qualification in the company side.

Table 1. The conversion of categorical values to numerical values filled by the company

Categories	Values	Scores	Impact
Specialty	Not candidate	0	0.35
	Candidate	1	
Degree	Secondary	1	0.05
	Diploma	2	
	B.Sc.	3	
	M.Sc.	4	
Experience	No experience	1	0.15
	< 1 year	2	
	2-3 years	3	
	4-5 years	4	
	>5 years	5	
GPA	Acceptable	1	0.1
	Good	2	
	Very good	3	
	Excellent	4	
Categories	Values	Scores	Impact
Certificate	No certificate	0	0.15
	1 certificate	1	
	More than 2 certificates	2	
Major	MIS or BIT	1	0.05
	AI and data science	2	
	Cyber security	3	
	Computer science	4	
Courses	No course	0	0.05
	1 course	1	
	2 courses	2	
	3 courses	3	
	4 courses	4	
Training	No training	0	0.1
	1 training	1	
	More than 2 training	2	

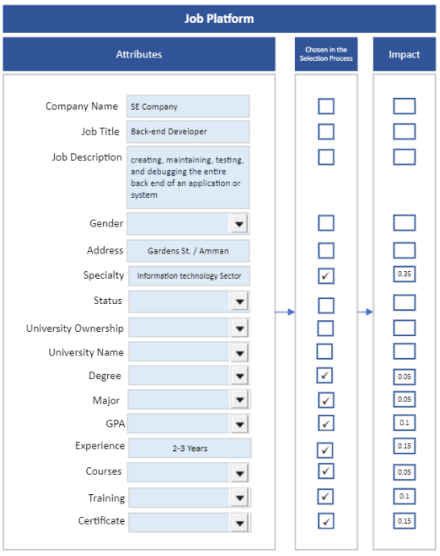

Figure 3. Required skills with the corresponding impact specified by the company

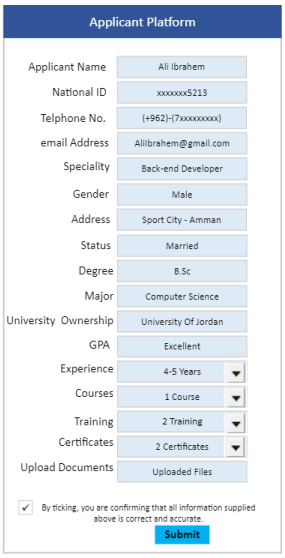

Figure 4. The requirements skills filled by the applicant

The results of this paper demonstrate a strong correlation between the computed proficiency score and the impact weight assigned by the employers to a specific job criterion, unlike the conventional selection used methods. The system's ability to recommend job opportunities to those whose proficiency score exceeds the average threshold, improves the precision of matching outcomes as well as enhances the effectiveness and the efficiency of the recruitment process.

Integrating proficiency-based rating system in the job-matching platform was presented in this paper. However, a deeper study might be needed to estimate its generalizability and scalability for different applicant format or various industry specific qualifications' standards. In addition, there might be a room to investigate the performance of real time processing in large scale recruitment environment. Moreover, further studies might be required to calibrate a dynamic learning scoring mechanism applied to different datatypes domain.

Our research shows that the proficiency-based ranking mechanism outperforms the traditional filtering technique. Future research may explore the scoring methods implementation by utilizing the machine learning technique and to incorporate the feedback from the employer to adjust the impact weights over the time in order to generate more dynamic and customized job-matching recommendations. Another avenue is to integrate the NLP for real time parsing to handle either the unstructured resume or the job description.

Recent studies indicate that the classical recruitment protocols lack of efficiency, fairness and openness specially when processing a huge applicants pool. Our findings prove that the suggested MJA model improves the decision-making with an explainable, fairness, data-drive applicant job matching. This is attached to the organized effect value allocation and computation efficiency which is achieved not just through increased candidate's data volume but also via smart impact weighted proficiency assessment and systematic filtering via bipartite graph analysis.

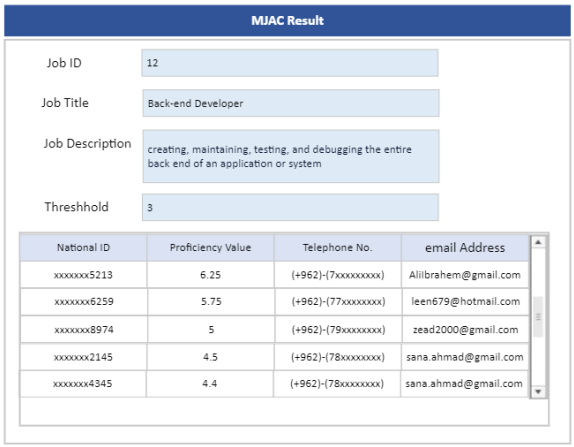

Figure 5. The MJAC results for a posted job company platform side

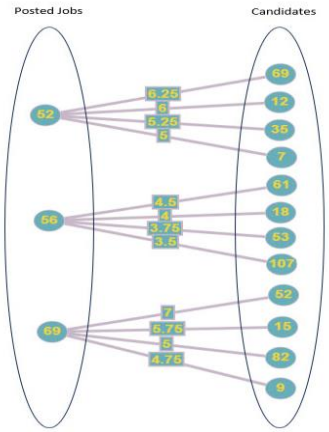

Figure 6. The MJAC results for all posted job in the company for the top 4-Candidates side

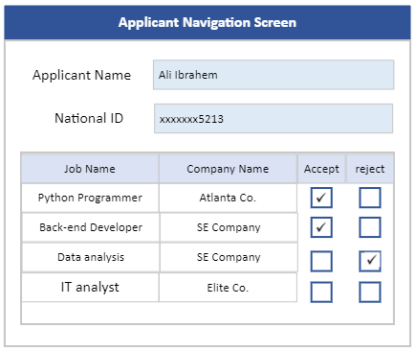

Figure 7. Applicant navigation screen

4. CONCLUSION

Improving the effectiveness of the selection process in the recruitment is a critical task for all businesses which requires significant resources and huge efforts. The MJA model helps companies and applicants at the same time. This is achieved by utilizing the mathematical machine which assures efficient unbiased solutions based on its deterministic stochastic nature. In this paper, electronic platforms were created to expedite the job matching process in Jordan. It starts by the companies that declared the possible job vacancies with the corresponding specified qualifications. Apparently, the company holds the responsibility of converting all categorical specified qualifications into numerical values, as well as, distributing the stochasticity that represents the impact of each specified qualifications in the posted job. From the applicant's perspective, the requirements skills are filled and submitted to the model. At the end, the MJAC method calculates the proficiency value of each applicant to the specific posted job. The most interesting feature in this model, the result is represented in a bipartite graph to manage the streamline of the recruitment process by presenting the k~candidate applicants associated and their proficiency values. Moreover, the applicant has the choice to accept or decline every job vacancy suggested by the model.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The Authors declare no conflict of Interest.

DATA AVAILABILITY

The dataset can be obtained upon requesrt frim the corresponding author.

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