Job Recruitment and Job Seeking Processes: How Technology Can Help

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This survey of current job search and recruitment tools focuses on applying a computer-based approach to job matchmaking. The authors present a semantic-based software platform developed in the framework of a European project on lifelong learning, highlighting future research directions.

Job seeking and recruiting processes have drastically changed during the past decade. Today’s companies are exploiting online technology (job portals, corporate websites, and so on) to make job advertisements reach an ever-growing audience. However, this advantage can create a higher post-processing burden for recruiters, who must sort through the huge amount of résumés and curricula vitae received, often expressed in different languages and formats. Similarly, job seekers spend considerable time filtering job offers and restructuring their résumés to effectively communicate their strong points and address the job requirements.

Consequently, job recruiters and seekers often use various special-purpose tools, such as job aggregators (including www.jobrapido.com and www.indeed.com) and social networks (including www.linkedin.com, www.glassdoor.com, and www.jackalopejobs.com). To further optimize selection processes with respect to processing time and accuracy, job portals such as Monster (www.monster.com) and Jobnet (www.jobnetchannel.com) have started to develop advanced search engines to automatically sort résumés based on job offer requirements. These approaches could exploit, among others, supervised and unsupervised learning, software agents, and genetic algorithms. Nonetheless, creating such tools is a complex task that requires identifying which variables influence the user’s final choice and defining ad-hoc ranking algorithms.
Furthermore, solving the job matchmaking problem—that is, finding the best match between job offer and demand—isn’t only a matter of processes and algorithms but also of the software system’s usability, especially for those with limited computer skills. In this respect, semantic technology can help, because the computer-based job matchmaking process can be configured to mimic human-like interaction and reasoning. In this article, we present a semantic-based software tool used for job matchmaking (see also our introductory video at http://youtu.be/yI9gNd_9g8E). First, however, we

**Computer-Supported Job Matchmaking Techniques**

**Supervised Learning-Based Techniques**

These methods exploit a set of training data to identify an inferred function that can predict the output value for each input element.

**Decision trees.** Predictive models that represent the output (the leaves) as the result of a combination of input variables (the internal nodes). This approach has been used to predict which job offers published online are relevant for a job seeker.¹

**Neural networks.** These data modeling tools can represent complex input/output relationships by mimicking the human brain’s behavior. This technique has been applied to matchmaking.²

**Unsupervised Learning-Based Techniques**

These methods use unlabeled data to distinguish between and explain key features.

**Ant colony optimization.** This metaheuristic reproduces the behavior of ants, who deposit an evaporating pheromone while searching for food to communicate with the colony. Other ants won’t cover previously explored long paths, thus avoiding the convergence to locally optimal solutions. This method is used to identify the variables with the strongest impact on the selection process.³

**Cluster analysis.** This statistics approach aims to create clusters of objects by maximizing similarities within a group and dissimilarities among objects belonging to different clusters. It has been used to support personnel assessment (in terms of identifying lateral moves or promotions, for example) by identifying “families” of employees within a company.⁴

**Genetic Algorithms**

These heuristics were inspired by Darwin’s theory about natural evolution, where a starting population (individuals) evolves by changing its properties (chromosomes). This approach could be used by a company that aims to fill some job positions, starting with internal or pre-screened external candidates.⁵

In this case, job candidates (chromosomes) are recombined to find better chains (individuals) optimizing the allocation of human resources to job positions.

**Software Agents**

These (semi)autonomous entities can accomplish (automated) tasks for users, such as collecting job offers or résumés.⁶

**Semantic Approaches**

These methods target the creation of self-descriptive and machine-understandable contents on the Web by adding appropriate knowledge on complex networks of relations among domain concepts. Semantic approaches let machines perform automatic processing over big and heterogeneous data by mimicking human reasoning processes.⁷

**References**

review the role of technology in today’s job recruitment and job seeking processes, showing how job matchmaking is an application area that stands to benefit from semantic technology.

**Semantic Job Matchmaking**

By leveraging machine-understandable models of the target domain, semantic-based systems can handle a variety of both structured and unstructured content, expressed in many languages, with different degrees of completeness, and in varying levels of detail. A semantic-based job matchmaking system can improve job matchmaking in numerous ways.

First, it can help job recruiters express job requirements in flexible ways, ranging from template-based forms to natural-language descriptions. Similarly, job seekers can flexibly express skills in their résumés.

Second, a context-aware semantic-based system can improve the user experience through better human-computer interaction. By applying contextual information, the system can help recruiters revise their position postings to better advertise their requirements, and it can help job seekers revise their résumés to better promote their qualifications.

Third, job offers and demands can be automatically matched—and a ranking of positions and candidates obtained—by considering concepts that aren’t explicitly mentioned in the job offers and résumés but that are semantically related to the terms that are used.

Finally, systems can suggest ways to improve such rankings—for example, through company-wide training or individual certification. (For more information, see the “Computer-Supported Job Matchmaking Techniques” and “Semantic Technology” sidebars. You can also see a related video at http://youtu.be/OGQ26dM_KjQ.)

There are a variety of approaches you can use to develop such a semantic job matchmaking system (see Figure 1a). However, regardless of the approach used, development should occur in three major phases (see Figure 1b)\(^9\)–\(^12\). The first phase should be devoted to creating a shared data model (a sort of “common language”) that defines standards for representing the information relevant for job recruitment and job seeking contexts in the

Moreover, with semantics, relations among concepts can be specified. A semantic-based search engine might manage incomplete queries and show pictures of other islands related to Java because they’re located in the same archipelago.

The knowledge management capabilities of semantic technology rely on the existence of suitable models, such as taxonomies and ontologies, to express the meaning behind the information handled. The models self-differentiate the relations managed. For example, taxonomies usually represent hierarchical classifications of concepts using trees of “is a” relations (“Java is an island,” for example). Within semantic-based processing, taxonomies are often replaced by ontologies. An ontology, defined as a formal, explicit specification of a shared conceptualization,\(^2\) is meant to model a variably shaped network of relations by also recording properties about concepts (such as “Java is the most populated island of Indonesia” or “Java is located between Sumatra and Bali”).

**References**

Figure 1. Development of a semantic job matchmaking system. (a) The various approaches used for development, (b) the three phases of development, and (c) the final results.

Semantic technology

A second phase targets annotation, where information provided by users (in job advertisements and résumés) is “augmented” with meta-information derived from the taxonomical and ontological models defined in the previous step. The annotation can be carried out automatically, semi-automatically, or manually. Different investigations can be done to find a reasonable mix of automation and user involvement, though the effort is often comparable to that of constructing the model itself.9

A third phase is devoted to defining the algorithms for measuring the semantic distance among concepts and actually computing the match. At this stage, the relations among concepts used for the annotation of résumés and job offers are navigated and weighted to evaluate similarities among competences possessed and required.

The final result produced by such a system depends on the matchmaking algorithm exploited, the quality of the model defined, and the accuracy of annotations made. Currently, the research is almost equally focused on the three phases, with the aim of finding effective solutions for an improved formalization, annotation, and computation of the match, while at the same time reducing the human workload and user expertise required.

Use Case: The LO-MATCH Platform

The Learning Outcome (LO)-MATCH platform (www.lo-match.polito.it) is a practical example of a semantic-based matchmaking system (see a demo of the system at http://youtu.be/l7j-7_SgFVU). It was developed as part of the MATCH project (http://match.cpw.org) and co-funded by the European Commission under the Lifelong Learning Program (http://eacea.ec.europa.eu/llp), which aims to support learning opportunities during all stages of life, from early childhood through to old age. With LO-MATCH, recruiters can advertise open positions and match them with résumés posted by job seekers to find potential candidates to interview. Similarly, job seekers can insert information related to previous education or work experiences, match the information with job offers published by recruiters, and receive a ranked list of job positions.

In our platform, the match between offer and demand is computed by considering the words in user achievements (or requirements) as well as the associated semantics—that is, the meta-information derived from suitable taxonomical
and ontological models. This way, dependencies on how information in résumés and job postings has been written are relaxed. In fact, a semantic system can operate beyond pure keyword-based comparisons, possibly enabling the exploration of partially matching contents expressed in different ways—for example, in another language, with different words, or with varying levels of detail.

**System Design**

While designing and implementing LO-MATCH, we paid particular attention to the following requirements:

- simplify the interactions and make the technological details transparent to users, and
- be flexible and provide valorization and acknowledgment of all experiences listed by job seekers or requested by recruiters.

We also made two key choices. First, we constructed the semantic model using the core concept of a learning outcome, which is what the European Commission is using to create a common language to easily translate across different countries, systems, and sectors what an individual knows, understands, and has accomplished in completing a learning process. We thus modeled résumés and job postings as collections of knowledge, skills, and competence elements, either acquired during formal or informal learning experiences or required for a given position. LO-MATCH is one of the first attempts to put into practice European strategies for lifelong learning in the context of job matchmaking.

Second, we relaxed the dependencies on the existence of an *a priori* strict language to formalize the domain. Although the richness of taxonomical and ontological models contributes to determining the effectiveness of semantic approaches, their design and maintenance costs can be very high. Moreover, sometimes defining complex relations among model elements can be even counterproductive. For example, what is the actual relation between programming and debugging abilities? Is it always correct to assume that if an individual can write a software program, then he or she can also debug it (or vice versa)?

**Ontology Development**

To create the LO-MATCH ontology, project partners started by identifying domain experts who could populate the LO-MATCH repository with learning-outcome-based statements belonging to professional profiles possibly owned or searched by job seekers and recruiters.

Next, this information was automatically related to the WordNet semantic thesaurus (http://wordnet.princeton.edu), where words were grouped in sets of synonyms, or “synsets,” with each one expressing a distinct concept, linked by both lexical and semantic relations.

A further ontological layer was overlapped in the platform repository by identifying key components—such as action verbs, knowledge objects, and context elements—and linking them to WordNet synsets.

Finally, the domain experts reviewed and fine-tuned this model.

**System Deployment**

We deployed a simplified user interface, targeting real-world users, enabling both the elicitation of acquirements or requirements and the computation of the match. Figure 2 shows some screenshots of how a job seeker can use the platform.

When a new résumé or a job offer is entered into LO-MATCH, the system complements it with additional information derived from the underlying knowledge base. Among possible operations in this and later phases, job recruiters and seekers can browse annotated profiles or perform a free text search and receive suggestions to better define required expertise (for the job posting) or personal experience (for the résumé). This feature strongly relies on the semantic-similarity properties among learning outcomes and it is aimed at filling possible information gaps and asymmetries throughout the process.

In our design, semantic similarity plays a central role in computing the match between job offers and demands:

- Starting from WordNet and the profiles knowledge base, semantic similarity is determined from concepts found and their network of relations.
- Job seekers and recruiters can flexibly tune the weights of the relations influencing the match, moving from pure keyword-based search to the full exploitation of semantic relations potential.
- The final outcome of the matchmaking is a list of companies and candidates that better match candidates’ characteristics and recruiters’ requests,
each linked to a semantic similarity-based score as well as to its distance from the corresponding expectations and needs.

The last feature is particularly useful for both user groups:

- Job seekers can get hints about missing competences to increase their chances of being hired by a given company.
- Recruiters can quickly and easily examine the different résumés, as well as identify candidates’ weak points, needing monitoring and reinforcement once hired.

Figure 3 shows a simplified example of how learning outcomes are compared in LO-MATCH. Learning outcomes possessed by job seekers are annotated (dotted line) according to the WordNet semantic thesaurus (central sphere), containing concepts (keyword boxes) and relations among them (solid lines among boxes).

Assuming that a recruiter is looking for an individual who can “autonomously exploit current...
apparel software applications,” the platform could suggest a candidate who can “draw dresses manually” (because of the relation between “apparel” and “dresses”) as well as someone who can “use, under supervision, CAD applications for the fashion industry” or “develop technical drawings using a PC program” (because of the relations between “software,” “PC program,” and “CAD,” among others). Once heterogeneously shaped contents have been brought to a common understanding, semantic distance between concepts can be exploited to provide the recruiter with ranked results so he or she can make a final decision.

**Testing and User Feedback**

In the MATCH project, the LO-MATCH platform represents the technological tool supporting a broad job placement methodology aimed at fostering the growth of cross-national and -cultural occupational opportunities in Europe. A piloting phase was carried out, focused on migrants. Although migrants are often qualified for available positions, their previous learning in their home country might be only partially acknowledged abroad. Furthermore, migrants might have difficulty interacting with job centers and hiring staff in the language of the receiving country.

Consequently, during piloting, the role of the platform was twofold. First, it enabled the development of an accreditation procedure for recognizing, validating, and certifying prior learning—that is, for constructing the migrant’s professional dossier (including the résumé) and issuing a corresponding vocational certificate. Second, it was used to implement the matchmaking by comparing certified learning outcomes with annotated job offers.

The methodology was implemented in “one-stop shops”—that is, platform-enabled job centers managed by the Chambers of Commerce and training institutions of six project countries. There, from February to December 2012, qualified operators provided guidance and coaching to more than 100 migrants. Almost all of them shared the same professional experiences—mainly as house or hotel cleaners, cooking assistants, health and social care operators, or shop assistants. Most of them also had previous formal learning at the secondary or vocational level. The platform let operators link both formal and nonformal learning to professional profiles recognized in the receiving country. For migrants without any previous experience, the platform indicated ways to fill the education and training gaps by showing learning outcomes most frequently requested for the available positions.

Résumés were then matched against job offers published by 54 employers and job agencies from the various participating countries. In almost all cases, the one-stop shop experience was followed by an interview at the employer premises (with the hiring staff confirming the validity of the platform-based selection process) or with the suggestion of (further) education or training actions.

During piloting, several issues were raised about platform usability that should be addressed before large-scale exploitation. One issue was related to the requirement to operate either in English or in...
the profile original language (because of the underlying ontology). Also, some employers complained about the need to insert data into “yet another platform.” A further problem related to the constrained set of reference profiles, which limited the expressive power of résumés. The last issue was the lack of a way to record evidence of previous formal and nonformal learning.

The project formally ended in March 2013, and there are plans to further address these issues and prepare the platform for “prime time” use. Such plans include introducing computer-supported translation functionalities, extending the ontology, and implementing suitable data integration strategies to automatically feed into the platform data coming from external repositories of national and sectorial profiles and job offers.

Job matchmaking is an important issue in today’s global, distributed, and heterogeneous job market. Future research should be tailored to reduce the dependency on experts and users by developing automatic strategies for a seamless integration of existing profiles, résumés, and job advertisement repositories with matchmaking platforms. Additional research and implementations could also be targeted to further strengthen system flexibility, identify suitable approaches for fully exploiting existing standards and classifications, and define and implement validation methodologies to evaluate and check the effectiveness and performance of automatic job matchmaking techniques.

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