

Ontologies and AI in Recruiting. A Rule-Based Approach to Address Ethical and Legal Auditing

Carmen Fernández Martínez¹[0000-0003-4514-4609] and Alberto Fernández²[0000-0002-8962-6856]

CETINIA, Universidad Rey Juan Carlos, Madrid, SPAIN

¹carmen.urjc@gmail.com

²alberto.fernandez@urjc.es

Abstract. Artificial Intelligence (AI) domain-specific applications may have different ethical and legal implications depending on the domain. One of the current questions of the AI is the challenges behind the analysis of job video-interviews. The use of semantic descriptions of jobs positions and candidate profiles could improve Recruiting information management within the organization and candidate-position matching. There are additional controversial issues, pros and cons to using AI in recruitment processes, and potential ethical and legal consequences for candidates, companies and states. There is a deficit of regulation of these systems, and a need for external and neutral auditing of the types of matching made in interviews to reduce potential discrimination, for example on the basis of race or gender, in the job market. We propose, first, formally define criteria for jobs and candidates using a candidate desired skills and emotions ontology and job offers ontology to foster interoperability at company level and a multi-agent system architecture for neutral auditing to guarantee a fair, inclusive and accurate AI.

Keywords: Domain Specific AI, Ethics, Human Resources, Ontology.

1 Introduction to research question and relevancy

Traditionally, Ai proved very valuable for resume and keywords scanning and for extraction of candidate skills devoid of bias. There has been a recent trend towards video-interview analysis in Human Resources. The survey by Personnel Today found that 38% of enterprises are already using AI in their workplace with 62% expecting to use it by 2018. In this research, we address such a current issue of the AI, the use of Machine learning techniques for analysis.

Concerning video-interview systems, there are limitations, some are attributable to the very nature of the technology (incorrect or biased datasets) and other are related to the human bias or the specific agenda of the recruiting company. However, the state-of-the-art in image analysis may allow pre-selecting with respect to age or sexual orientation or other controversial characteristics. The analyses could lead to ethical and legal consequences (e.g. in some countries is forbidden to ask for age in processes). This is why fostering proper auditing of video-interview systems it is particularly important.

The initial entry point of the system and settings will be the set of interview questions designed by Human Interviewer, later distributed to the hiring candidates. The output will be a ranking/list of candidates plus reports and warnings. The video interview produced in subsequent stages will be subjected to general and customized analysis. Several features will be measured and tracked according to the recruiter choices, to name but a few: Is there only a person appearing in the video? How long does it take to answer (candidate time)? Does the candidate look directly into the camera (eye time)? Does the candidate have a high score of percentage in commercial profile. As a result, the analyses could track global behaviour traits like attention to detail (eye contact time, emotions-intonation and body language).

Results will be clustered, later on, to finally being analyzed with AI using techniques like K-NN, Adaboost or Neural Networks.

2 Problem statement

There has been a recent trend towards video-interview analysis in HR departments. Traditionally, AI played no more than an assistant role in HR, e.g. resume and CV scanning. But lately, apps and systems like HireVue¹, Montage², SparkHire³ and WePow⁴ have been changing how recruitment is carried out. An AI-based video interview system analysed with Machine Learning techniques could be programmed to check, during an interview, features such as age, lighting, tone of voice, cadence, keywords used (substantial conversation), mood, behaviour (eccentric, movement or quite calm and not talkative), eye contact and, above all, emotions. AI targets the specific traits of a customer-oriented role that employers want in their teams.

AI has produced benefits for HR so far, including recruiting time and customised questions and answers and lack of interviewer bias (physical appearance, tattoos, etc.) But there are several problems that accompany the use of these technologies; for example, candidates are unfamiliar with video-interview analysis (for example, lighting, settings), which could affect global performance. It is necessary to point out the Gender and racial bias and the imprecision of technology. Traditionally, machine learning algorithms were trained with data from white people or biased datasets.

We studied several potential controversial characteristics, among them, facial symmetry, race, gender, sexual orientations in voice and image recordings. The problem of racial-bias in AI is not new, just like the detection of mixed race in bad lighting conditions according to Siyao et al. [1]. As an illustration of the advances in sexual orientation recognition both in images and sound, one study [2] needed ethical supervision due to the opaque invasive nature of the research and the use of real user data from dating applications. Researchers argue that there is a relationship among homosexuality, morphological features e.g. jawline and exposure to particular concentrations of hormones in the womb.

With reference to Ethical and legal aspects of AI, whilst the use of AI in this context may have its benefits, it also strips away aspects of humanity, reducing a human recruit to a set of descriptors. The automation of HR processes could lead to potential ethical and legal implications that cannot be ignored. In some countries, companies are not allowed to ask a candidate's age during recruitment. Especially in

¹ <https://www.hirevue.com/>

² <https://www.montagetalent.com>

³ <https://www.sparkhire.com>

⁴ <https://www.wepow.com/es>

the United States where is forbidden to "improperly classify or segregate employees by race". (US Civil Rights Act, 1964).

Given the illustration of the problem above mentioned, we want to achieve *automatisation of analyses in Human Resources that guarantee compliance and auditing* of the questions posed to the candidates considering differences in legislation and national scenarios. Secondly, we aim for accuracy and suitability of the data sets used for training and test of learning algorithms, looking if it is fair to extrapolate their classification results to different regions and backgrounds. If not possible, *the option of notifying by means of warning the irregularities in datasets or in an interview format*. We then will *elaborate on the assumption that Agents are the right paradigm to support this problem*. Agents could be defined as distributed nodes of information that could carry out the automatic analysis independently from one another. The software agents of our proposal assist the Human Resources employees and candidate in the automatisation and completion of tasks. Finally, *we strongly believe in the benefits of adding semantic Web knowledge to the agents*. For instance, *HR domain-specific ontologies* could not improve interoperability or reuse of information. They could also very well boost the ability of learning and therefore better and more accurate reasoning and automatisation, helping human employees in their knowledge discovery and decision process, duties that could be taken over by a new Discovery agent in the MAS architecture.

3 Related work

The complicated issue of handling of unstructured data in big organisations and the ontology-based solutions to deal with it is a recurring topic in previous work. In the specific case of Human Resource data, the proposed solutions are mainly related to the extraction of information from Resumes [5] and ontology-based information extraction system for matching résumés to job openings [6].

Regarding the implementation of the auditing system, Multi-agent systems pose similar challenges concerning information formats that traditional complex distributed systems and the problem is more acute in firms.

The *current approach* is the definition of agents tasks and implementations and the exploration of both MAS and ontologies and shared lexicons, which foster domain specification and interoperability, an idea supported in previous works [3] so as to the introduction of MAS in complex corporate settings such as manufacturing industry.

The idea of coordination and interoperability of agents in heterogeneous domains has been widely used in many different domains, such as health care, emergencies due to natural disasters [8], smart cities [9], etcetera. Multi-agent systems (MAS) have also been used to improve business processes in complex organisations. Practicalities of big multinational corporations, the difference in formats and regulations make it necessary to create vocabularies and ontologies, architectures and models to rule over changing specific agent populations. Architectures have been proposed to deal with the random and quick changes of a particular productive section, such as the manufacturing industry but could be applied to other dynamic corporate environments [10]. The recruiting scenario in a multinational context is also quick and complex and needs models. So far there is no much literature related to applications of HR and MAS as enabling technology, but these types of architectures have been extensively used, as noted above, in manufacturing and corporate control production (e.g. Ciortea et al. [10]).

Additionally, we supported our research on previous works in legal formalization [4]. The domain of Law or Legal formalization is open to MAS applications and has been addressed over the last decade by Law scholars such as Walker. It is important for rules-based systems a proper model of the legal rules. Legal requirements modelling (as knowledge acquisition) is a specialized field nowadays, celebrating conferences such as International Conference on Legal Knowledge and Information System (JURIX).

4 Research question

RQ1: How to achieve an improvement of interoperability in Recruiting. Is it applicable to a use case/controlled business scenario?

RQ2: How to achieve accurate automatization in domain Human Resources.

RQ3: Is it possible to implement a comprehensive legal auditing or compliance system given the current state-of-the-art?

The first research question is related to the improvement of interoperability, full automatization and better ethical and legal auditing in Recruiting. To promote the interoperability we will follow an ontology-based approach for information extraction from video-interview systems analyzed with Artificial Intelligence. Then it will be possible to extract the information of interest regarding the candidate and the traits and competencies analyzed in the video-interview and reformulate all in a structured document to make easier the auditing and compliance process with Labour Law.

Similarly, for the third research question, the introduction of ethical and legal auditing test in the domain we will consider Multi-Agent System, rules engines to prove the appropriateness of this approach.

5 Hypothesis and Proposal

The hypotheses behind our research is that automatization of tasks, the use of ontologies and semantic descriptions and the introduction of proper auditing could improve the business processes in Human Resources. The research questions outlined in the previous section will be addressed following these hypotheses:

(RQ1) H1: Describing semantically interview formats, CVs and job positions makes easier attempting to do ontology matching and fostering interoperability in a cross-cultural international business scenario.

(RQ1) H2: The extraction of facts, entities and relations from unstructured data like video-interview stream or images is a manageable problem, given the current state-of-the-art in visual analyses.

(RQ2) H1: The automated analyses and reasoning in Human Resources are tangible.

(RQ2) H2: The inclusion of search and discovery, learning capabilities in HR software agents are tangible.

(RQ3) H1: The rule-based approach can produce a fair ethical and legal test. The rule-based approaches are a more efficient solution to implement a compliance system.

(RQ3) H2: MAS is the right paradigm to handle legal auditing in a Human Resources environment.

To prove the above-mentioned hypotheses and solve the research problem of interoperability I am going first to approach the creation of ontologies for jobs positions, résumés and characteristics related to the analysis of facial expressions in

video-interview. The inclusion of semantic technology, the better definition of international corporate terms, in general, the knowledge representation, could indeed be helpful in discovery and searches of information. The software agents could, therefore, be able to show learning capabilities, e.g inclusion of discovery agents in the architecture.

Most AI data analytics applications for Recruiting are based totally on unstructured or not categorized data. Once the proposal of ontology for this domain is finished, it will favor the automatization without human intervention and the automatic legal auditing of the recruitment processes. The most relevant innovation of this proposed work will be the attempt to automatise part of this legal and ethical auditing as well as some analyses carried out by the different distributed agents. It has been attempted in previous work in corporate business processes, not HR. Many sectors have adopted an intelligent process automatisation technology so far. Activities like data extraction, creation of reports without human intervention, access to databases are now usual.

The *specific contribution* and progress made thus so far is mainly the proposal of semantic descriptions for Human Resources and a Multi-agent systems architecture for auditing HR [Fig 1]. Additionally, there has been prototyping of some parts -legal rules engine.

With reference to the ontologies for Human Resources, we have found essential to define the traits in relation to competencies assessed in a recruitment process. For example, the trait Engagement analysed by emotions detector Affectiva and others is the result of very different candidate features. The systems test the candidates on grounds of different emotions that could be a potential match for the jobs positions, emotions such as *Anger, Contempt, Disgust, Engagement, Joy, Sadness, Surprise and Valence*.

$engagement = \exists hasBrowRaise. BrowRaise \exists hasBrowFurrow. BrowFurrow \cap \exists hasNoseWrinkle. NoseWrinkl \dots \exists hasLipCornerDepressor. LipCornerDepressor \dots \exists hasChinRaise. ChinRaise \dots \exists hasLipPucker. LipPucke \dots \exists hasLipPress. LipPress \dots \exists hasMouthOpen. MouthOpen \dots \exists hasLipSuck. LipSuck \dots \exists hasSmile. Smile$

Engagement implies gestures such as brow raise, brow furrow, nose wrinkle, lip corner depressor, chin raise, lip pucker, lip press, mouth open, lip suck and smile.

Other features such as the estimated age of the candidate age are listed in categories or rank like enumerated types. *Face.Age (18-24, 25-34, 35-44, 45-54, 55-64, 65_PLUS, under_18, unknown)*

5.1 Towards automated support for auditing HR. Rules-based approach

The main objective of the auditory will be the legal check carried out by Labour Law agent when necessary. We consider a rules-based approach to achieve this. It is assumed that the interviews will have a great amount of confidential information and private responses but when necessary, they will be processed by the external Law agent to make sure there are no infringements of Labour Law of the countries carrying out the process.

In the first place, with the aim of simplifying our reasoning, it was proposed to write up simple Labour Law measures existing in a particular country using the format of rule and include/exclude as a result of executing the rule. The first analysis for simplicity will be checking the legal age of the candidate and then the analysis will focus more specifically on advanced criteria to avoid discrimination. For example, biased decisions tracked in the Natural Language processing of interview towards hiring individuals of certain age <40 or native speakers only, or women only

or individuals of certain sexual orientation. The bias will be displayed in the form of informative warnings.

E..g Spanish Labour Law rule format

Age>18=>include

Age<=18 AND emancipated AND consent parents/tutor=>include

Age<=18 AND not emancipated AND non authorized =>exclude

Age <=18 AND not emancipated AND authorized mother AND consent father=>include

Age <=18 AND not emancipated AND authorized father AND consent mother=>include

Age <=18 AND not emancipated AND total orphan AND authorized legal tutor=>include

Age <=18 AND not emancipated AND total orphan AND not authorized legal tutor=>exclude

Age <=18 AND not emancipated AND partial orphan AND authorized mother=>include

Age <=18 AND not emancipated AND partial orphan AND authorized father =>include

Age <=18 AND not emancipated AND partial orphan AND not authorized mother=>exclude

Age <=18 AND not emancipated AND partial orphan AND not authorized father =>exclude

Age>60 AND legally retired=>exclude

Age>60 AND not legally retired=>include

Age>60 AND legally retired AND active retirement status=>include

The Ethical check carried out after pre-selecting individuals by gender or age merely based on fiscal benefit for the employers and positive discrimination.

Age<30 AND first employment=> Warning

Age>45 AND long-term unemployment=>Warning

Gender=Woman AND domestic violence victim=>Warning

Terrorism victim=>Warning

As previously mentioned, we have resolved to include a rule engine to implement the *LegalClassifier*. Rule engines are used nowadays to filter spam emails or to restart passwords, subscribe/unsubscribe user.

We intend to codified first Laws from Codes, Statutes and formal sources, resulting in up to 100 rules organized in rule files specific for every country. The rules files are based on the salience of rules, that means that the very basic rules like legal age to enter the workplace will have greater salience values than the rules that constitute legal and ethical warnings. Any other different sources of Law or Regulation, like specific collective bargain agreements, could be considered in future releases.

The implementation is just for interview text format and is supported by files including Labour Law of Spain, US or others. The interview information will be integrated with candidate data and interview responses in the later stages of our research. The output of the classifier will be include, exclude meaning if an interview format is not compliant with the basic legal rules and needs to be discarded.

The warning option is essential to contemplate the cases that are being discriminatory or biased to a certain minority group- but that not break any existing law. The idea is the implementation of neutral auditing but it is understandable that

countries promote and work towards access to the job market of women, unemployed youth and minorities.

It is evident that the legal issues concerning candidates, such as the identification of race and sexual orientation in the selection process due to the advances in image processing, entails ethical questions that cannot be ignored. Careful analysis from auditing bodies, governments, ethics committees and psychologies is needed. In this section, we describe a proposal of a multiagent software architecture for auditing, which is depicted in Fig. 1.

Fig. 1 shows an abstract MAS architecture that must be adaptable to different international corporate environments and by recruiters of different nationalities in search of international compliance. The challenge of storing legal knowledge and doing sound checks and reasoning become complicated in cross-jurisdictional cases.

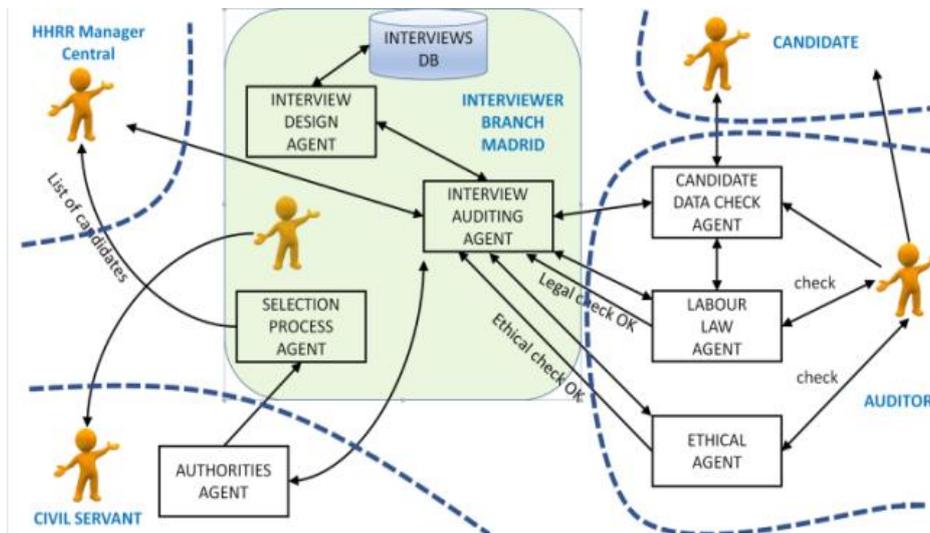


Fig. 1. Multi-agent systems architecture

The core of the architecture comprises three different parties that must collaborate: (i) a recruiter/company, (ii) external auditor, and (iii) government/authorities. An *Interview design agent*, based at the company central headquarters, is responsible for designing a general interview. The first action in the use case would be the opening of a new general position by the HR manager. The interview design agent will later translate the requirement to design customized interviews applying the general interview format to a regional scenario of the country where the recruiting is taking place. The *Interview auditing agent* is based in company branches and will watch the specific national requirements necessary for the process. The Selection process agent can cancel the process due to controversies or give back a list of candidates to the central office if the process is fair. It is also capable of running checks with authorities and auditors. If the features analysed in the recruiting process break any law or if the process contravenes basic civil rights, the interview process agent would ask for the approval of the *Labour Law Agent* or *Ethical Agent* if necessary. If the recruiting process is dealing with a candidate's personal information, it would require the candidate's approval.

Interview generator agent. In order to design and compare different and fair interviews, an *interview design agent* is required. It would be located next to the company main headquarters. According to company requirements, some interview profiles could be designed to be recruited thereafter internationally (e.g. software engineer, marketing expert). The input of the agent would be certain characteristics of the open position, controversial or not, (experience, commercial role, age>40, gender=woman, English native speaker, Spanish native speaker). The output would be the interview questions in natural language for a particular role together with scores and answers and rankings expected for the role (optimism 50%, commercial profile 60% etcetera). It is expected that the total implementation will require the use of technologies such as RDF or ontologies as a starting point to define and harmonize the formats. Once the interview has been designed is submitted to the database to be reviewed thereafter by the in-company auditing agent.

Interview in-company auditing agent. The *Interview in-company auditing agent* manages the selection processes in different branches. The human recruiters select a particular generalist interview from the corporate database for a concrete role, for instance, analyst. It applies the general format to every regional scenario, e.g. Europe, Asia Pacific, and the Middle East, adapting the candidate criteria to be selected to culture. The agent controls interactions among human recruiters and decides if it is essential to pass interviews with additional stages if they handle controversial data. The Input would be a generic interview format (later redistributed among HR team) and output Boolean true/false if it needs auditing. In the cases when the information needs further validation it is passed to other agents. All the legal and ethical transactions are hosted outside of the company, in external auditing bodies and governmental premises. The recruiting process could end at this very point if the questions are simple and do not need legal handling.

Selection Process agent. The *Selection Process agent* is the main element of the proposed Multiagent System. It is hosted near the company branch where the selection process is being held. It is in charge of processing the different events that occur in the system (new interviews, new auditing and legal checks, authorities, etc.), triggering new events when necessary and providing a ranking of candidates to the human interviewer. It could occasionally reuse interviews from other companies, it coordinates different companies, external neutral auditors and authorities, but only if necessary. In case no external auditing is needed –no controversial issues are found– the Selection Process agent provides direct feedback of the candidate.

Candidate data Check Agent. Once the candidate dossier arrives at the external auditors it may happen that, due to the sensitivity or inaccuracy of the data, some confirmation or permission from the candidate is required to proceed with the data handling. Since the main purpose of this Multi-Agent System is to assess the selection process in each and every phase the *Candidate data Check Agent* would inform promptly the company side if a candidate denies confirmation or does not give consent to the data.

Labour Law external auditing Agent. The human auditor could optionally proceed with legal tests. The analyses are very convenient since the *Labour Law agent* runs different checks in different legislation, specifically focusing on Employment Laws.

The Labor Law agent allows to easily adapting to new legal scenarios considering multiple countries and jurisdictions. In the case of law infringement, it would inform the main agent, i.e. the Selection process agent.

Ethical agent. In the case the user data are very controversial and address ethical issues, e.g. the interview is designed to check for age or sexual orientation it would be necessary to complete a check by the *Ethical agent*, which would support the analysis with ethics committees and experts to make a verdict on the excessive invasion of the interviewee privacy. The output of this agent would be ethical approval or disapproval. The ethical agent would be addressed by the interview auditing agent. In case it checks any subtle irregularity in candidate criteria database, both positive and negative discriminations, the auditing agent launches a check for the ethical agent. E.g. candidate and homosexual=>exclude, candidate and heterosexual=>include. Candidate and transsexual=>include.

Authorities agent. In the case a company is expatriated and recruiting international candidates, an *Authorities agent* coordinates different government's decisions and must decide whether a company must comply with additional proceedings or if it is needed to check register of a foreign candidate in a city census. Once the final check is completed the information flows back to the Selection process agent who is responsible for closing the selection process or cancelling it on legal/ethical grounds.

6 Preliminary Results and/or Evaluation Plan

Concerning limits, so far I am in the process of producing theoretical work and submitted automatization of legal auditing/ prototyping of legal rules engine concerning Spanish and US Law. The proposal has been widely accepted by my scientific department and a brief description of the project published in ERCIM news, a publication gathering relevant research carried out by European research groups.

As the doctoral work advances, we will see if we could address in all detail the architecture or just the automatization of the legal auditing if it involves hundreds of rules. There is an absence of affordable and limited testing opportunities of real corporate applications so we are counting on prototyping on a simulated corporate scenario. The testing is very dependent on data availability, use of different ontologies and the real attributed measured by video-interview systems. Legal reasoning entails the correct formalization of laws and technical supervision of jurists.

The refinement of the algorithm for detection of bias would seem necessary here in our evaluation plan. For instance, if a candidate is excluded for valid reasons but happens to also be homosexual, the system should decipher whether exclusion is a result of bias or not.

The rules engine so far includes rules for detection of candidates allowed to work according to Spanish legislation, considering age, underage workers with a permit to work, active retirement and the query of race and sexual orientation for unethical purposes. In Spanish legislation, the candidate is not often asked about personal issues not even for survey purposes, like in the United Kingdom. One supposes that an expert in Law should translate the legal language of various legislations into rules. In addition, I have a background in Law but I consider this process does not entail major difficulty because laws are reduced to a very simple set of preconditions (age>18 and so on).

At this point of research, we are using a case study to demonstrate the workflow through the entire system just as prototyping in a simulated corporate environment. We will soon begin the test with real corporate data transferred from other academic departments. The main emphasis for improvement should be on the ethical agent and more detailed analyses that extrapolate the results from systems Affectiva and HireVue, that documented very well the traits measured, to all HR products.

7 Approach

There is not much work directly in this area at the moment and we are trying to consolidate a broad range of thinking linked to the topic. In an attempt to address the research questions, we are keen on breaking new ground in critically examining both current and potential issues with the use of AI in HR.

The possibility of reusing ontologies was examined in the early stages. The existing standards and popular ontologies in Human Resources describe many aspects of job positions, sectors and activities [11] but need to be up to date to the current application of technology in the sector. We finally consider not to implement them from scratch. Nevertheless, the field of investigation we consider, the analysis of video-interview through Machine learning techniques, the interview formats and so on, requires the extension of these ontologies.

8 Reflections

As a conclusion, we summarize the expected results. The **contribution of this PhD** is, therefore, the automatization. The benefits of our research will be a step forward in the accurate automatization of tasks in Human Resources and ethical and legal analyses of video-interview techniques. The trend is towards full automatization. The work could break new ground in critically examining and auditing the video-interview systems so as in providing semantic description and ontologies for job positions/interviews and candidate criteria and competencies. Due to the global nature of the companies, this could mean a step forward in interoperability in an organization and third parties, states and auditing bodies.

Taken into account all that have been stated, it should be pointed that my approach gathers evidence of real video-interview systems analyzed with AI and includes is based on a thorough analysis of HR business processes, going beyond other approaches that deal only with the information extraction of résumés, LinkedIn pages and personal blogs and matchmaking of job positions/candidate résumés. Considering the additional detailed study of Labour Law in different legislation it is to be expected that the rules engine is precise and likely to be applicable to real scenarios. Finally, we will prove the effectiveness of a rules-based approach for this system.

Acknowledgments.

Work partially supported by the Spanish Ministry of Science, Innovation and Universities, co-funded by EU FEDER Funds, through grants TIN2015-65515-C4-4-R and RTI2018-095390-B-C33.

References

1. Siyao F., Haibo H., Zeng-Guang H. Learning from Face: A Survey. *IEEE Trans. Pattern Anal. Mach. Intel* 36(12): 2483-2509 (2014).
2. Kosinski M. and Wang. Y. Deep neural networks are more accurate than humans at detecting sexual orientation from images. *Journal of Personality and Social Psychology*, 114(2):246–257, (2018).
3. DiLeo J., DeLoach S. Integrating ontologies into multiagent systems engineering. Air Univ Maxwell AFB AI centre for Aerospace Doctrine Research and Educ. (2006).
4. Walker, V.R.. A default-logic framework for legal reasoning in multiagent systems. *AAAI Fall Symposium - Technical Report*. 88-95. (2006).
5. Darshan, P. M. Ontology-based information extraction from resume. In 2017 International Conference on Trends in Electronics and Informatics (ICEI) (pp. 43-47). IEEE. (2017).
6. Celik, D. Towards a semantic-based information extraction system for matching résumés to job openings. *Turkish Journal of Electrical Engineering & Computer Sciences*, 24(1), 141-159 (2016).
7. Ossowski, S., Omicini, A., Coordination knowledge engineering. *Knowledge Engineering Review*, 17(4), 309–316. (2002)
8. E. Mas, A. Suppasri, F. Imamura, S. Koshimura. Agent-based simulation of the 2011 great east Japan earthquake/tsunami evacuation: An integrated model of tsunami inundation and evacuation, *Journal of Natural Disaster Science*, 34(1), 41-57 (2012).
9. Billhardt, H., Fernández, A., Lujak, M., Ossowski S., Agreement Technologies for Coordination in Smart Cities. *Applied Science*, 8(5), 816. (2018)
10. Debenham, J., A Multi-Agent Architecture for Business Process Management Adapts to Unreliable Performance, In: Parmee I.C. (eds) *Adaptive Computing in Design and Manufacture*, V. Springer, London, DOI: 10.1007/9780-85729-345-9_31 (2002)
10. Ciortea, A., Mayer, S., Michahelles, F., Repurposing Manufacturing Lines on the fly with Multi-agent Systems for the Web of Things, In *AAMAS '18: Proceedings of the 17th International Conference on Autonomous Agents and MultiAgent Systems*, Proceedings of the 17th International Conference on Autonomous Agents and Multiagent Systems, (pp. 813-822), (2018)
11. Gómez-Pérez, A., Ramírez, J., Villazón-Terrazas B., An ontology for modelling human resources management based on standards. *International Conference on Knowledge-Based and Intelligent Information and Engineering Systems*. Springer, Berlin, Heidelberg (2007)