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Doctoral Consortium

Proceedings

Mirjam Minor (Editor)

Preface

It is my pleasure to collect in this volume the high quality contributions of six young scientists who aim to achieve their PhD in the field of Artificial Intelligence. The work will be presented in a PhD workshop at KI 2022 which takes place online in Trier Germany, September 20, 2022. I would like to thank the committed team of reviewers and mentors comprising of Fabian Lorig, Thomas Lukasiewicz, Özgür Özcep, Ute Schmid, Dietmar Seipel, Marcel Waleska, and Diedrich Wolter. A special appreciation deserves Stefan Edelkamp who will give a career talk “To PhD or not to PhD, that’s the question”. Thanks also to the organisers from University of Trier having provided us so kindly with the necessary infrastructure, Webpage and help in any further issue that occurred. I am looking forward to listen to the oral presentations, to discuss the manifold topics and research questions and to learn more about the people who make the doctoral consortium at KI 2022 a success.

Enjoy reading!

Mirjam Minor
Doctoral Consortium Chair
Goethe University Frankfurt, Germany

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Conference Paper Assignment Problem - A new system for recommending and assigning reviewers to scientific articles.

Ana Carolina Ribeiro[0000-0003-1557-654X]

DEI/FEUP - Department of Informatics Engineering, Faculty of Engineering of the University of Porto.
LIACC - Artificial Intelligence and Computer Science Laboratory
up201602840@edu.fe.up.pt

1 Introduction

The recommendation and assignment of reviewers to articles, generally called in the literature as Reviewer Assignment Problem (RAP), has become an essential topic in the academic world. RAP can be seen as a version of the Generalized Assignment Problem (GAP), and Conference Paper Assignment Problem (CPAP) is a specific case of RAP [1].

In most cases, articles should be assigned to reviewers according to the following conditions: (i) Each manuscript should be assigned to a certain number of reviewers, a_i, defined by the team responsible for assigning the reviewers; (ii) as far as possible, each article should be assigned to reviewers who are experts in the field. A specific limit T can be defined to identify the qualification of the reviewers; (iii) each reviewer should be assigned to, at most, a certain number of articles, b_j, defined by the team responsible for assigning the reviewers; (iv) each reviewer should be assigned to approximately the same number of articles, to balance their workload.

Given a set P={1, …, |P|} of articles and a set R={1, …, |R|} of reviewers, c_{ij} denote the matching degree of article i for reviewer j, where i belongs a P and j belongs a R. A binary variable x_{ij}, whose value is 1 if article is assigned to reviewer j and 0 otherwise, RAP is formulated by the following integer programming formulation (REFs):

$$RAP: \max \sum_{i \in P} \sum_{j \in R} c_{ij} x_{ij} \quad (1)$$

Subject to

$$\sum_{j \in R} x_{ij} = a_i \quad (2)$$

$$\sum_{j \in P} x_{ij} \leq b_j \quad (3)$$

$$x_{ij} \in \left\{ \left\lfloor \frac{c_{ij}}{T} \right\rfloor \right\} \quad (4)$$

$$x_{ij} = 0,1 (5)$$

$$max_{j \in R}\{c_{ij} x_{ij}\} \geq T (6)$$

The objective function (equation 1) maximizes the total matching degree of the assignment. As first two constraints (equation 1 and 2) ensure that the conditions (i) and (ii) are satisfied, respectively. The fourth constraint (equation 4) along with the fifth constraint (equation 5) prevent a reviewer being assigned to an article whenever c_{ij} is smaller than the given threshold T. The sixth constraint (equation 6) instead of the fourth constraint (equation 4) is brought into the mathematical model to ensure that at least one reviewer whose matching degree for article i is higher than or equal to T.

The peer-review system is considered the main mechanism for quality control of scientific publications [2], with the potential to contribute to the rigour of the work published in the academic community [3]. The challenging task of the peer-review process is to recommend and assign suitable reviewers whose interests and research profile fit appropriately in the submissions [4]. Often these tasks are still done manually by editors or conference organizers. However, there are obvious flaws in the method of selecting and manually assigning reviewers to articles. Firstly, this is a time-consuming process. The committee of conferences or journals needs to retrieve databases from expert researchers and find the most suitable ones for each submitted article. Second, it is common to recommend expert researchers in the same research area as the article to be reviewed. However, there are many other indicators that should be considered when selecting reviewers, for example, publications, research projects, patents. Also, teams that select reviewers use titles, rewards, and status to assess the quality of the experts. Third, the process of manually selecting and assigning reviewers to articles ignores possible relationships between reviewers and authors. Finally, since it is necessary to manage a large amount of information about the reviewers and the articles submitted according to human and subjective criteria, bias may occur in the recommendation and assignment of researchers.

According to the problems presented above, there is a need to apply intelligent technologies capable of analyzing data, extracting valuable information from documents and unstructured texts, and thus automatically recommending and assigning the most appropriate researchers to scientific articles. This doctoral study aims to solve the CPAP through the development of a system capable of recommending the most appropriate and expert reviewers and efficiently assigning them to scientific articles, according to the established constraints.

2 Motivations

The development of automatic and efficient mechanisms for recommending experts has a high economic value. These mechanisms allow the increase in productivity, which transposes into finding experts in a valuable search time and increasing efficiency, ensuring the highest possible level of correspondence between their profile and task. In the scientific world, these expert recommendation mechanisms provide the added value of inferring and identifying research teams and working groups, especially between researchers from different institutions; discover emerging talents with

low visibility; support students, allowing them to identify the best supervisors and co-supervisors of master or doctoral degrees.

Also, it is essential to keep the quality standard of science high. The review of scientific articles in scientific conferences and journals, and scientific projects is one of the best-known tasks for expert researchers. The recommendation and assignment of the most suitable experts to the articles are based on human and subjective criteria, which can generate wrong decisions, such as the rejection of excellent scientific work or a potentially successful project proposal. These decisions can have significant and adverse effects on the quality of the scientific standard, namely, the quality of published studies, researchers' careers, and the reputation of conferences and journals.

Por estas razões, é essencial estudar métodos automáticos e imparciais que apoiem o processo de recomendação e atribuição de investigadores experts aos artigos científicos submetidos numa conferências e que o tempo de processamento dos pedidos seja o mais curto possível.

3 Objectives

The present PhD study aims to develop a Recommendation System (RS) based on constraint programming solvers applied to the CPAP case. A more detailed description of the objectives is as follows:

1. Development of a data collection system capable of collecting relevant input information from researchers who are candidates for reviewers and from scientific articles.
2. Development of an Information Extraction system combining deep neural networks and advanced NLP techniques in extracting the semantic representation of scientific articles' content and reviewers' information gathered.
3. Development of an expert RS capable of extracting the expertise level of reviewers and finding the ranking of expert reviewers in a given research topic(s)/area(s).
4. Search, compare and select available open-source next-generation constraint programming technology solvers and other recent optimization approaches to deliver the best trade-off between efficiency and ease of integration and customization.
5. Integration of the constraint programming-based constraint solving module in the developed RS.

4 Research Questions

According to the previously context, motivation and objectives, some research questions arise, namely:

1. How can the CPAP be formulated as a constraint programming problem?
2. What is the effect of deep neural networks combined with natural language processing techniques in extracting the semantic representation from the content of scientific articles?

3. Do CP solvers frameworks allow to handle reviewers' constraints in the context of assigning articles more efficiently when compared to other current solving approaches?
4. Do CP solvers frameworks improve the balance between efficiency and ease of integration and customization compared to different methods?

5 Related Work

RAP has two main phases – 1) finding/recommending expert reviewers and 2) assigning reviewers to submitted manuscripts. These problems are different and therefore require different approaches. In phase 1), the main objective is to compute the article-reviewer similarity factors depending on the method (implicit or explicit) chosen to describe the articles and the competencies of the reviewers. While in phase 2) the main objective is the effective assignment/allocation of expert reviewers to scientific articles.

According to the literature, different approaches can be applied in phase one, namely: decision support systems [5], [6], recommendation systems [7], [8] and machine learning-oriented approaches [9], [10]. In phase two, we can find studies developed with optimization approaches based on heuristics and meta-heuristics [11], [12], fuzzy approaches [13], answer set programming [14], and other.

Finding expert reviewers (phase 1) generally requires the development of relevant tasks such as collecting data on the reviewers and, sometimes, on the authors of submitted articles; the construction of the profiles of reviewers and articles submitted and, finally, the computation of the similarity between reviewers and authors. The approaches based on DSSs and RSs have several similarities in their processes. For example, the development of the reviewers' profile and articles submitted through the specific measures (quality, relevance, authority, diversity, among others) have been shown to achieve good results in recommending reviewers [5], [15]; The information retrieval process is also common in the approaches, relevant and includes the classification of publications, the author's disambiguation (for example, rule-based algorithms, clustering-based algorithms), the extraction of relevant information (for example, LDA algorithm, Doc2Vec model, TF-IDF), among others; finally, in the similarity calculation between reviewers and articles, the similarity of cosine ordered weighted averaging aggregation function and Kullback-Leibler divergence are the most commonly used techniques and with better results.

The problem of assigning/allocating reviewers to submitted articles (phase 2) presents several types of approaches tested by researchers. The approaches based on heuristic and metaheuristic algorithms have a strong presence in researchers' studies [11], [16]. Also, the greedy and genetic algorithms are the best known and selected by researchers to try to solve the attribution problem. Other approaches, such as the fuzzy approach [17], ASP [14] or integer linear programming, also aroused the interest of researchers and showed good results.

6 Approach

The defined approach proposes the construction of knowledge about the expertise of researchers and the recommendation and assignment of the most appropriate expert reviewers for scientific papers. The proposed system comprises four modules:

1. Data Collection Module – The main purpose of this module is to collect data from multiple data sources (open databases and Web) to create a database with information about researchers (affiliations, co-authors, citations, number of publications, awards, among others) and scientific articles (metadata).
2. Information Extraction Module – The main objective of this module is to extract relevant information from the data, transforming it into more significant representations of its semantic content and, consequently, easier to analyse. This module combines advanced NLP techniques and deep neural networks for the extraction of semantic and contextual information from the collect data.
3. RS of Experts Module – This module focuses on the recommendation of reviewers' experts in a given research topic/area. The relevant information extracted in the previous module allows the construction of reviewers' profiles (based on quality, reputation, and expertise) and scientific articles (based on metadata and key insights). Subsequently, the objectives of RS are to extract the behavioral model of experts, compute de expertise level of each reviewer and, finally, present the ranking of experts.
4. Assignment Module – In this module, the main objectives are the definition of the constraints of assignment of reviewers to scientific articles and the implementation of a sophisticated optimization approach (constraint programming) to enforce the adequacy of the recommended reviewers to the input constraints and requirements.

7 Evaluation

The system validation starts with the comparison of the results obtained in this study with the results found in the literature of approaches used by other researchers to solve the RAP. Furthermore, we intend to validate the system in a real environment, namely, in a scientific conference. At this stage, we want to compare the results of recommendation and attribution of our system with the results of the conference system. In addition, we intend to assess the satisfaction of reviewers through a survey.

8 Contributions

The main expected contributions of this PhD study are:

1. Development of an RS to be integrated into a constraint resolution module based on sophisticated constraint programming and optmization approaches to handle constraints more efficiently when compared to other current constraint resolution approaches.
2. Study the effect of using Deep Neural Networks in extracting semantic representation of scientific papers' content and researchers' contents for the recommendation task.

Acknowledgments. This work was financially supported by: Base Funding -UIDB/00027/2020 of the Artificial Intelligence and Computer Science Laboratory – LIACC - funded by national funds through the FCT/MCTES (PIDDAC). The first author is supported by FCT (Portuguese Foundation for Science and Technology) under grant PD/BD/2020.04698.BD.

References

[1] D. Hartvigsen, J. C. Wei, and R. Czuchlewski, "The conference paper-reviewer assignment problem," *Decis. Sci.*, vol. 30, no. 3, pp. 865–876, 1999, doi: 10.1111/j.1540-5915.1999.tb00910.x.

[2] L. Bornmann, "Scientific Peer Review," in *Annual Review of Information Science and Technology*, 2011, pp. 199–206.

[3] R. H. Fletcher and S. W. Fletcher, "The effectiveness of journal peer review," 2003. doi: 10.1302/0301-620x.82b8.0821208c.

[4] J. Goldsmith and R. H. Sloan, "The AI conference paper assignment problem," in *AAAI Workshop - Technical Report*, 2007, vol. WS-07-10, pp. 53–57.

[5] D. T. Hoang, N. T. Nguyen, B. Collins, and D. Hwang, "Decision Support System for Solving Reviewer Assignment Problem," *Cybern. Syst.*, vol. 52, no. 5, pp. 379–397, 2021, doi: 10.1080/01969722.2020.1871227.

[6] T. Pradhan, S. Sahoo, U. Singh, and S. Pal, "A proactive decision support system for reviewer recommendation in academia," *Expert Syst. Appl.*, vol. 169, no. November 2020, p. 114331, 2021, doi: 10.1016/j.eswa.2020.114331.

[7] C. K. Kreutz and R. Schenkel, "RevASIDE: Assignment of Suitable Reviewer Sets for Publications from Fixed Candidate Pools," *ACM International Conference Proceeding Series*. pp. 57–68, 2021, doi: 10.1145/3487664.3487673.

[8] Y. Yong, Z. Yao, and Y. Zhao, "Beyond Accuracy: A Feature Crossing Method for Chinese Thesis Reviewer Recommendation," in *Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics*, 2021, pp. 1151–1158, doi: 10.1109/SMC52423.2021.9658668.

[9] L. Cagliero, P. Garza, A. Pasini, and E. Baralis, "Additional Reviewer Assignment by Means of Weighted Association Rules," *IEEE Trans. Emerg. Top. Comput.*, vol. 9, no. 1, pp. 329–341, 2021, doi: 10.1109/TETC.2018.2861214.

[10] D. Zhang, S. Zhao, Z. Duan, J. Chen, Y. Zhang, and J. Tang, "A multi-label classification method using a hierarchical and transparent representation for paper-reviewer recommendation," *ACM Trans. Inf. Syst.*, vol. 38, no. 1, pp. 1–20, 2020, doi: 10.1145/3361719.

[11] C. Yang, T. Liu, W. Yi, X. Chen, and B. Niu, "Identifying expertise through semantic modeling: A modified BBPSO algorithm for the reviewer assignment problem," *Appl. Soft Comput. J.*, vol. 94, p. 106483, 2020, doi: 10.1016/j.asoc.2020.106483.

[12] D. K. Pradhan, J. Chakraborty, P. Choudhary, and S. Nandi, "An automated conflict of interest based greedy approach for conference paper assignment system," *J. Informetr.*, vol. 14, no. 2, p. 101022, 2020, doi: 10.1016/j.joi.2020.101022.

[13] K. Mittal, A. Jain, and K. Vaisla, "A novel method for reviewer assignment problem based on reviewers' profile and fuzzy graph connectivity measure.," in *International Conference on Intelligent Engineerjng Management*, 2020, pp. 4–9.

[14] G. Amendola, C. Dodaro, N. Leone, and F. Ricca, "On the application of answer set

programming to the conference paper assignment problem," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 10037 LNAI, pp. 164–178, 2016, doi: 10.1007/978-3-319-49130-1_13.

[15] M. Maleszka *et al.*, "A Modular Diversity Based Reviewer Recommendation System," in *Intelligent Information and Database Systems*, vol. 1179, 2020, pp. 550–561.

[16] Y. Kalmukov, "An algorithm for automatic assignment of reviewers to papers," *Scientometrics*, vol. 124, no. 3, pp. 1811–1850, 2020, doi: 10.1007/s11192-020-03519-0.

[17] K. Mittal, A. Jain, and K. S. Vaisla, "Understanding Reviewer Assignment Problem and its Issues and Challenges," in *Proceedings - 2019 4th International Conference on Internet of Things: Smart Innovation and Usages, IoT-SIU 2019*, 2019, pp. 1–6, doi: 10.1109/IoT-SIU.2019.8777727.

A multi-agent based framework for controlling self managing fleets of autonomous vehicles with a transparent reasoning process

Marcel Mauri[0000−0002−4135−1945]

Department of Computer Science, Goethe University, Frankfurt am Main, Germany
mauri@cs.uni-frankfurt.de

Abstract. This dissertation aims to research on multi agent systems to develop a base system to control a fleet of self-driving and self-organizing vehicles with a transparent reasoning process. The main focus for the application area is on the use in mobility as a service/ride hailing scenarios. Every vehicle will be controlled by a belief-desire-intention agent and will use utility functions to make its decisions. The agents will delegate unfavorable jobs to each other by using the contract net protocol for a decentralized decision making.

Keywords: BDI Agent · Multi-agent system · Mobility as a Service · Simulation · XAI

1 Introduction

Due to climate change growing scarcity of resources we have to reconsider parts of our way to live. One of these is the mobility sector which offers great potential for optimization. A new and much more efficient way to move could be mobility as a service (MaaS) which means to buy "mobility services as packages based on consumers' needs instead of buying the means of transport" [8]. A specialization of MaaS where every passenger is served by a single autonomous vehicle is called ride-hailing [12].

MaaS solutions based on a free floating model that are designed to cover the last few meters, such as the bike and scooter sharing services that are widely used today, have some problems. They tend an accumulation of vehicles in remote, inconvenient or dangerous places. To cover this, additional employees are needed to permanently pick up the vehicles and place them at locations with higher customer traffic.

This dissertation is part of a project that uses a multi agent system (MAS) to develop a self driving and self-organizing fleet of E-trikes which are intended to be used in a free float model. This system is designed to be an improvement of the above described already available sharing services. The vehicles will drive autonomously to the position of a calling customer, search proactive for useful parking positions when not in use, drive to a charging station when needed and communicate with each other to find the most suitable E-trike for every incoming

job. Every vehicle will be controlled by an BDI agent. Customer orders are first delegated to the nearest vehicle. This vehicle will use a utility function to decide if the customer job can be handled by itself. If not it will use the contract net protocol (CNP) to delegate it to a more suitable E-trike. For this decision, the utility function will take into account, among other things, the already accepted customer trips, the current battery level and expected arrival times. By using the BDI architecture, each agent can think about the order and the way in which it performs its tasks, which include customer, loading and parking trips.

As trust is an important factor between interactions of humans and AI systems [6] we want to achieve this for the framework. The reasoning process should be transparent and decisions should be explainable to the user (e.g. why there is currently a waiting time). Also further predictive explanations should be provided (e.g. user wants to know how much longer he has to wait).

In a first step the advantages of such a system will be examined in a simulation, later it is planed to build two prototypes which will be tested in real life on the university campus. This dissertation focuses on the development of the MAS and the evaluation by using a simulation. The development of the hardware or software components, that does not belong the decision making (like the obstacle detection as part of the autonomous driving), is not part of this thesis. The MAS developed in this dissertation will be designed in such a way that it is suitable as a basic framework for use in other scenarios with autonomous self-managing vehicles.

2 Motivation

The individual technologies and methods in this dissertation are all well studied in their own right. Their combined use for the upper described use case, especially in the context of XAI, seems new and not much researched. An evaluation of the possibilities of such a combination seems to be an interesting research gap.

Multi-agent approaches in context of traffic scenarios are discussed in [1]. BDI agents are well known and have already been used for vehicles in projects that are to some kind comparable to this [13] but mostly focused on the design of the agents and without an performance evaluation. There are projects which researches similar problems but differ in the detail. So [9] uses neither BDI agents nor the CNP. There are research projects in ride-hailing, but without the use of BDI agents for the vehicles [7]. There are also highly scalable decentral approaches for decision making but without the communication aspect of this project [3]. Projects that use both, BDI agents and a utility function, are not in the context of ride hailing [4]. The decentralized decision-making approach is also not widespread. In projects with an similar application scenario centralized approaches seem to dominate. [11]

3 Research Question

The goal of this dissertation is to develop a MAS framework with a transparent reasoning process that can be used to control a fleet of cooperating autonomous self-organizing vehicles usable for various application scenarios. Although this MAS framework is intended to be usable for a variety of application scenarios, the focus is on ride-hailing with e-trikes as described above.
The aim is to find a reasonable balance between the achievability of the goals (in the case of the ride-hailing scenario the waiting/driving times or customer losses) and the energy consumption of the overall system.

Research Question: How can a MAS framework for self-driving autonomous vehicles be developed, to provide a transparent reasoning process for users across different application domains?

To date, the following sub questions have been found that should be answered:

- How does such a MAS compete with traditional/already existing solutions in terms of the achievability of its goals?
- How does such a MAS compete with traditional/already existing solutions in terms of the resources required?
- How does the different features of the MAS influence the results mentioned above?
- Can the user understand the decisions made by the agents' reasoning process at any point in time?

4 Approach and first Results

With the BDI architecture, a suitable agent architecture has already been identified for the project. The list of tasks that an agent has to fulfil changes regularly. Therefore, it is necessary for the agent to keep thinking about the best possible plans to fulfil them. For the communication between the agents the contract net protocol have been identified as a possible solution. Initial results have already been collected with a simplified prototype based on the JADE [2] agent framework [5]. For the use in a cyber-physical system planned in a later project phase, a separation between agent framework and simulation environment is aimed at. For this purpose it is planned to connect BDI agents implemented in Jadex with the Matsim simulation environment [10].

5 Planned Evaluation

The capability of the developed multi agent system will be evaluated by using simulations. One part of the evaluation will take place in the former described ride-hailing scenario. Therefore it is planned to use different configurations to

compare the actual influence of the the special abilities of the system (ability to communicate, to delegate trips, proactive charging and parking trips) with different evaluation criteria. Criteria such as the energy consumption of the entire fleet, waiting and travel times, and the loss of customers due to delays can be used for the evaluation. Corresponding tests are to be repeated with different scheduling strategies, parking behavior and loading behavior. It is also planed to measure the benefits of the MAS compared to a much simpler, already available ride-hailing system and an centralized optimization approach.

It is considered to evaluate the capability of the MAS in an other application scenario to show the universal applicability. This could for example be a garbage collection scenario. In the process, the MAS will control autonomous trucks that must efficiently collect trash from various locations. The details of the evaluation of this scenario and the XAI component are not yet elaborated.

References

1. Bazzan, A.L.C., Klügl, F.: A review on agent-based technology for traffic and transportation. The Knowledge Engineering Review **29**(3), 375–403 (Jun 2014)
2. Bellifemine, F., Caire, G., Greenwood, D.: Developing multi-agent systems with JADE. Wiley series in agent technology, Chichester, reprint. edn. (2008)
3. Danassis, P., Filos-Ratsikas, A., Faltings, B.: Anytime Heuristic for Weighted Matching Through Altruism-Inspired Behavior. IJCAI 2019 pp. 215–222 (2019)
4. Deljoo, A.: What Is Going On: Utility-Based Plan Selection in BDI Agents. The AAAI-17 Workshop on Knowledge-Based Techniques for Problem Solving and Reasoning (2017)
5. Erduran, Ö.I., Mauri, M., Minor, M.: Negotiation in ride-hailing between cooperating bdi agents. In: Proceedings of the 14th International Conference on Agents and Artificial Intelligence - Volume 1: ICAART,. pp. 425–432. INSTICC, SciTePress (2022)
6. Jacovi, A., Marasović, A., Miller, T., Goldberg, Y.: Formalizing trust in artificial intelligence: Prerequisites, causes and goals of human trust in ai. In: Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency. p. 624–635. FAccT '21, Association for Computing Machinery, New York, NY, USA (2021)
7. Jaroslaw Kozlak, S.P., Zabinska, M.: Multi-agent models for transportation problems with different strategies of environment information propagation. PAAMS 2013, Springer Berlin Heidelberg (2013)
8. Kamargianni, M., Li, W., Matyas, M., Schäfer, A.: A Critical Review of New Mobility Services for Urban Transport. Transportation Research Procedia **14**, 3294–3303 (2016)
9. Malas, A., Falou, S.E., Falou, M.E.: Solving On-Demand Transport Problem through Negotiation. Proceedings of the Summer Computer Simulation Conference p. 7 (2016)
10. Padgham, L., Nagel, K., Singh, D., Chen, Q.: Integrating BDI Agents into a MATSim Simulation. Proceedings of the Twenty-first European Conference on Artificial Intelligence pp. 681 – 686 (2014)

11. Pavone, M.: Autonomous Mobility-on-Demand Systems for Future Urban Mobility. In: Maurer, M., Gerdes, J.C., Lenz, B., Winner, H. (eds.) Autonomes Fahren, pp. 399–416. Springer Berlin Heidelberg (2015)
12. Qin, Z.T., Tang, X., Jiao, Y., Zhang, F., Xu, Z., Zhu, H., Ye, J.: Ride-Hailing Order Dispatching at DiDi via Reinforcement Learning. INFORMS Journal on Applied Analytics **50**(5), 272–286 (Sep 2020)
13. Rüb, I., Dunin-Keplicz, B.: Basta: Bdi-based architecture of simulated traffic agents. Journal of Information and Telecommunication **4**(4), 440–460 (2020)

Cognitive Learning Agents for Autonomous Mobility on Demand systems

Ömer Ibrahim Erduran[0000−0002−1586−0228]

Department of Computer Science, Goethe University
Frankfurt am Main, Germany
erduran@cs.uni-frankfurt.de

Abstract. In my PhD thesis, the concept of Cognitive Agents with extended Learning capabilities for Autonomous Mobility on Demand (AMoD) scenarios is investigated. Specifically, the focus is set on the Ride-hailing concept with a fleet of autonomously driving vehicles. The agent-based approach provides the possibility to consider cognitive agent architectures for different types of agents in the given scenario. In this regard, the vehicle agents are built up based on the Belief-Desire-Intention (BDI) architecture. My dissertation combines two paradigms that are considered significant research areas, namely Machine learning (ML) and Agent-oriented Programming (AOP). Therefore, a structured overview of the research made so far is provided pointing out significant areas in the AMoD application scenario which are worthwhile to work on. For each of the areas, I describe why the setting and combination of MAS and ML are relevant and interesting for in-depth investigation.

Keywords: Cognitive Agents · BDI Agent · Machine Learning · Agent-oriented programming · Mobility on Demand · Multi-Agent system

1 Introduction

The basis of my dissertation relates to work in Multi-Agent system (MAS) research, which has been studied over the last decades [8]. Advances in Deep Learning have made remarkable progress in data-driven learning approaches. Using extensive computational processing for Reinforcement Learning, it is likewise possible to make achievements in different applications. Due to the proliferation of ML techniques in multi-agent scenarios, which have appeared especially recently [7], the concept of MAS is particularly prominent in ML research, where multiple agents are interacting with each other to accomplish a common goal. In this work, a MAS consisting of autonomous *software agents* is considered with explicitly programmed capabilities. A software agent is an entity that interacts with its environment by sensing information and producing actions. In the field of cognitive software agents, the most predominant agent architecture is the *Belief-Desire-Intention* architecture, in short BDI, which is based on the *sense-think-act* cycle of cognitive agents. The main characteristic of cognitive software agents is that the capabilities which the human calls intelligent behavior has to

be hard coded into the agent architecture. In ML whereas, the intelligent behavior of the considered learning agent emerges during the learning phase. In the underlying scenario of AMoD, certain challenges are investigated and extended with ML methods. This dissertation aims to address the issue of extending cognitive agent models with ML capabilities and provides initial results considering the mentioned application scenario. Integrating ML techniques is a recent and open issue in Agent-Oriented Programming [4,8,12]. For example, one of the key limitations of the BDI architecture is the lack of generating new plans during processing [3]. In a traffic simulation environment, the learning procedure of the agent is then evaluated. The results of this dissertation will provide insight into different approaches to integrating learning capabilities into the BDI agents interacting in a MAS. Moreover, a novel approach to learning in a MAS with BDI agents is presented investigating the potential and limitations of the framework.

2 Problem formulation and Related work

The underlying problem formulation is based on the *Dynamic Pickup and Delivery problem* (DPDP) [1], which is a variation of the *Vehicle Routing Problem* (VRP). Given is a *trip request* d_i with a passenger, a potential set of trip requests R and a complete and directed graph $G = (V, A)$ with a node set $V = \{0\} \cup \{i^+ \mid i \in R\} \cup \{i^- \mid i \in R\}$, which means that V contains the origin and destination of all trip requests and moreover, the vertex 0 which represents the *depot*. Furthermore, an edge set $A = \{(i, j) : i, j \in V, i \neq j\}$ is considered, where each edge $(i, j) \in A$ has a non-negative length or cost c_{ij} and a non-negative travel time t_{ij}. At each time step t, each vehicle $k \in K$ is either serving a node, waiting at a node, or moving towards a node. The vehicles can decide to *accept* or *reject* a trip request [1]. Solving VRP and DPDP is already tackled with ML approaches [9,11]. In [9], the problem of fleet management is formulated as a Multi-agent Reinforcement Learning problem. Here, the MAS is learning as a whole to dispatch and reposition vehicles. In the work of [14], different assignment strategies with flexible parameters for a variation of vehicle allocation are investigated and compared with each other. In [2], an overview of fleet management problems and approaches is presented containing optimization approaches for different scenarios, but neglecting learning approaches. Finally, [10] presents a mixed-integer program for optimizing vehicle sharing systems. The approach in my work differs from the works mentioned, since I consider the BDI agent architecture and integrate ML into the agent reasoning cycle.

3 Current state

So far, I investigated the representation of the considered application scenario as well as concrete research questions. The addressed research questions in my work are focused on the interaction between the cognitive BDI architecture which is enhanced with learning capabilities and its effects to the AMoD simulation environment. The primary question of my research is: *To what extent can cognitive*

BDI agents benefit from learned behaviors? This question addresses the issue described in the previous chapter. More specifically, I consider Deep Learning algorithms influencing the decision-making of the BDI agents. Thus, I analyze the effects of learning by investigating the BDI reasoning steps, like *goal selection* as well as the effects in the simulation environment.

- *How can Neural Networks enhance the decision making of BDI agents?*
- *Which tasks are suitable for ML in Mobility on Demand?*
- *What are the effects of multiple cognitive BDI agents learning in an MAS?*

In my first work, I tackled the fleet positioning of vehicle agents with cluster analysis using generated GPS coordinates and open-source customer trip requests from a bike-sharing fleet [6]. In the second work, I worked on the application scenario representation considering the BDI agent architecture and a trip request negotiation process [5]. Due to the mentioned requirements, extensive research has been done to investigate development platforms for software agents as well as Mobility on-demand simulation platforms. Here, I picked out JadeX [13] as an agent development platform and MATSim [15] as the traffic simulation environment. The main characteristic of JadeX is that Goals and Plans are formulated explicitly. Therefore, I currently investigate the learning behavior on a goal level for BDI agents which addresses the decision-making step. MATSim and JadeX are implemented in Java. The integration of ML algorithms is therefore also considered in Java. The library *DL4J* [1] provides Deep Learning and Reinforcement Learning algorithms that will be applied to the BDI agent cycle.

4 Planned contributions

The core contribution of my thesis is the investigation of the BDI architecture connected with learning capabilities. As an application scenario, the ride-hailing application is considered. The subject of my research is therefore an agent architecture, where different intelligent capabilities and concepts are investigated with the focus on learning algorithms as extensions. The research environment is the development of a fleet management system with high-level learning strategies for cooperating autonomous vehicles in Mobility on Demand scenarios. In the following, the specific contributions are described.

4.1 Fleet Management

The first task considers the whole vehicle fleet and its utilization starting with the positioning and rebalancing of the vehicle agents. In general, a fleet coordination challenge is addressed. This problem is tackled using spatio-temporal data and self-organizing and communicating agents. One research direction is focusing on challenges that arise during the processing of the fleet. Since the vehicle agents contain a cognitive thinking phase, a travel time prediction component will be

[1] https://deeplearning4j.konduit.ai/

integrated into the agent's thinking phase leading to more informed decisions and actions. Finally, the battery charging behavior of a fleet is investigated which also influences the decision-making of the vehicle agents. Here, the avoidance of running out of battery power is one central question. This challenge will be tackled with Reinforcement Learning by training the BDI agents to learn battery management.

4.2 Decision making

The second task contains multiple contributions and represents the main part of my thesis concerning the cognitive part, where learning capability is employed in the BDI cycle to decide about committing to customer trip requests. Similar to the work of [4], I consider the question of integrating Reinforcement Learning methods in the BDI architecture for the decision-making of vehicle agents. Considering different agent capabilities, I compare different agent types including learning agents. Starting with a single vehicle agent and its decision-making, the question is extended to the whole fleet representing a MAS with cognitive learning agents. The certain task is the trip assignment step. In this case, a utility-based negotiation is considered as well as a learned utility function with Deep Reinforcement Learning (DRL), where the decision is based on the corresponding reward function.
The communication of agents in MAS is significant for coordination. In the BDI architecture, a common method to realize communication is using standardized predefined speech acts. The messaging process requires an extensive engineering process, where each messaging type and direction has to be considered in order to provide communication to the MAS. Learning when to communicate with other agents is crucial for efficient problem-solving. Furthermore, learning on a fleet level is a novel approach for cognitive BDI agents which has to be investigated since nearly all of the works published in this intersection, focus on the single-agent setting.
Since the decision-making steps inside the typical BDI agent is predefined, some steps are suitable for specific ML algorithms. During *Goal selection*, the agent decides, which *Goal(s)* it should pursue and thus which *plans* it should process. Learning which goal to pursue is a novel approach in BDI and ML integration. This approach will be investigated with decision trees and neural networks as well as evaluated in the AMoD simulation environment.

5 Conclusion

This dissertation focuses on a variety of integration methods for cognitive agent architecture and ML methods in a Mobility on Demand application. The presented areas are tackled in current research with a variety of approaches. Fundamentally, my approach considers AOP for ML as well as the given application scenario of ride-hailing and therefore differs from the majority of current work in this area. The contribution of my dissertation delivers cognitive software agents

enhanced with ML techniques processing in a BDI manner. The mentioned open issues in the previous section lead to a need for a thorough investigation of cognitive agents that are capable to learn. Since they are used for industrial applications, this research intersection of considering cognitive agents for AMoD enables the investigation for novel research insights with respect to autonomy in MAS and fleet applications.

References

1. Berbeglia, G., Cordeau, J.F., Laporte, G.: Dynamic pickup and delivery problems. European journal of operational research **202**(1), 8–15 (2010)
2. Bielli, M., Bielli, A., Rossi, R.: Trends in models and algorithms for fleet management. Procedia-Social and Behavioral Sciences **20**, 4–18 (2011)
3. Bordini, R.H., El Fallah Seghrouchni, A., Hindriks, K., Logan, B., Ricci, A.: Agent programming in the cognitive era. AAMAS **34**(2) (Oct 2020)
4. Bosello, M., Ricci, A.: From Programming Agents to Educating Agents – A Jason-Based Framework for Integrating Learning in the Development of Cognitive Agents. In: EMAS, pp. 175–194. Springer International Publishing (2020)
5. Erduran, Ö.I., Mauri, M., Minor, M.: Negotiation in ride-hailing between cooperating bdi agents. In: Proceedings of the 14th ICAART Volume 1. pp. 425–432. INSTICC, SciTePress (2022)
6. Erduran, Ö.I., Minor, M., Hedrich et al., L.: Multi-agent Learning for Energy-Aware Placement of Autonomous Vehicles. In: the proceedings of ICMLA 2019. pp. 1671–1678. IEEE, Boca Raton, FL, USA (2019)
7. Foerster, J., Assael, I.A., De Freitas, N., Whiteson, S.: Learning to Communicate with Deep Multi-Agent Reinforcement Learning. Advances in NeurIPS **29** (2016)
8. Guerra-Hernández, A., El Fallah-Seghrouchni, A., Soldano, H.: Learning in BDI Multi-agent Systems. In: Computational Logic in Multi-Agent Systems, vol. 3259, pp. 218–233. Springer Berlin Heidelberg (2004)
9. Jin, J., Zhou, M., Zhang, W., Li, M., Guo, Z., Qin, Z., Jiao, Y., Tang, X., Wang, C., Wang, J.: Coride: joint order dispatching and fleet management for multi-scale ride-hailing platforms. In: Proceedings of the 28th CIKM (2019)
10. Nair, R., Miller-Hooks, E.: Fleet management for vehicle sharing operations. Transportation Science **45**(4), 524–540 (2011)
11. Nazari, M., Oroojlooy, A., Snyder, L.V., Takác, M.: Deep reinforcement learning for solving the vehicle routing problem. arXiv preprint arXiv:1802.04240 (2018)
12. Padgham, L., Sardina, S., Sen, S.: Incorporating learning in bdi agents (01 2008)
13. Pokahr, A., Braubach, L., Lamersdorf, W.: Jadex: A BDI Reasoning Engine. In: Multi-Agent Programming, vol. 15, pp. 149–174. Springer US, Boston, MA (2005)
14. Regan, A.C., Mahmassani, H.S., Jaillet, P.: Evaluation of dynamic fleet management systems: Simulation framework. Transportation research record **1645**(1), 176–184 (1998)
15. Singh, D., Padgham, L., Nagel, K.: Using MATSim as a Component in Dynamic Agent-Based Micro-Simulations. In: Engineering Multi-Agent Systems, pp. 85–105. Springer International Publishing (2019)

Model Transformation in Description Logics
Motivation and Approach

Willi Hieke

Technische Universität Dresden, Institute of Theoretical Computer Science
https://tu-dresden.de/ing/informatik/thi/lat
willi.hieke@tu-dresden.de

Abstract. In the field of knowledge representation and reasoning, description logics are commonly used to design knowledge bases and to reason about this knowledge. Various algorithms have been introduced to solve common reasoning problems, some of which compute models of the knowledge bases. There are, however, reasoning services that require models to admit certain properties not taken into consideration by these algorithms. This, for instance, is the case for explaining reasoning results using models. Consequently, our research goal is to identify desired model properties and to define appropriate model transformations as well as to investigate the computational complexity of these transformations.

Keywords: Description Logic · Model Transformation · Explainable AI.

1 Introduction

Knowledge representation and reasoning (KRR) is a well-established branch of artificial intelligence (AI) that is concerned with modeling information as logical statements in knowledge bases in order to apply reasoning algorithms. A commonly used family of knowledge representation languages is description logics (DLs), which usually are decidable fragments of first-order logic (FOL) and closely related to modal logics [17]. They formalize knowledge about edge and vertex-labeled, directed graphs. DL knowledge bases are frequently used to formalize domain specific knowledge as they, for instance, constitute the foundation for W3C standardized ontologies in the OWL 2 standard.

One main advantage of DLs is that they provide formally defined and well-investigated reasoning problems. DL reasoners decide many reasoning problems, such as satisfiability, by computing a model of the knowledge base under consideration. Usually, the respective reasoning procedures are implemented in highly optimized reasoning algorithms [10]. However, DL reasoner systems usually compute models according to their optimization criteria and do not take other factors, such as comprehensibility, into account. In fact, reasoning results can be hard to comprehend for users of DL systems as DL knowledge bases can easily grow very large and complex. This is the reason for an ongoing active development of various syntactic and semantic approaches for explaining logic-based AI reasoning.

Consequently, this project is concerned with the transformation of models of DL knowledge bases such that the resulting model satisfies additional properties, which depend on the use case. More precisely, we identify desired properties of models to, for instance, serve as explanation, and define according model transformations as well as investigate their computational complexity.

2 Motivation

A main motivation for the manipulation of models of DL knowledge bases is, as mentioned before, explanation of reasoning results. Some reasoning results computed by DL systems can be far from obvious due to a number of reasons, e.g. because of the size and complexity of the respective knowledge base or because of a lack of familiarity with the logical syntax and deduction steps. There are, in principle, two ways of explaining reasoning results of DL systems for users. First, the reasoning result should be deducible in a logical calculus in case of positive entailment. This approach seems natural for positive entailments but less striking for explaining negative entailments. We take the path of explaining reasoning results semantically, which is the second way of explaining. This means we provide suitable models as prototypical examples to users in order to explain positive reasoning results, and we present suitable counter examples in case of negative reasoning results.

DL reasoner systems are optimized in terms of efficient computation of reasoning results. Hence, the computed models can appear artificial and counter-intuitive to users of DL systems. In order to make the reasoning result based on the computation of a model more comprehensible, the model can be transformed into another model of the DL knowledge base that admits additional properties, which shall foster human understanding of the reasoning result under consideration. For instance, possibly small models could ease comprehension since they do not contain redundancies. To identify interesting properties and discuss their meaning for improving model based explanations is part of this project. Besides, a mere visualization of the knowledge base by a well-shaped model can already help users to understand their knowledge base without having to read all its logical formulae, which already requires a certain level of expertise.

Of course, one can transform models for various purposes other than to improve explainability. The need for transforming models becomes evident whenever a use case requires the model of the knowledge base to satisfy an additional property that is not expressible in the respective DL. For instance, the well-investigated DL $\mathcal{ALC}$, and hence any less expressive DL, admits the tree model property, meaning that no $\mathcal{ALC}$ knowledge base can enforce its models to be tree-shaped or prevent them from being tree-shaped because tree-shapedness is not expressible in $\mathcal{ALC}$. Hence, if the knowledge base is meant to model tree-shaped structures, such as pedigrees, transforming models into tree-shape while simultaneously maintaining their model property w.r.t. the given knowledge base can be useful.

3 Research Goal

In short, the general goal of this project is to define, investigate, and provide instances of a model transformation framework for specifying mappings over models of DL knowledge bases such that the images satisfy additional constraints while maintaining their model property. In this framework, the desired property is a parameter, as is the respective knowledge base. This framework can then be used to define and discuss concrete instances of it as well as to classify model transformations w.r.t. the parameters of the framework.

This implies two aspects. First, the search for properties and use cases in which model transformations are useful. For these cases, we define appropriate transformations and proof their soundness. Second, the investigation of such framework w.r.t. general aspects, such as the computational complexity of model transformations given a certain logical language in which the desired model property is formalized. Such a language could be monadic second-order logic (MSO), or any other language that is more expressive than the DL in use.

The ideal of this research line would then be to construct an automated service for model transformations with user definable properties.

4 Related Work

Explainabilty of logic-based AI reasoning is an active research area with various approaches, see e.g. [6, 15]. On the syntax side, one approach computes a minimal set of logical statements from the knowledge base that produces the entailment to be explained. These sets are called justifications and were intensively investigated in recent years [14]. Another syntax-based approach is to provide comprehensible proofs [1]. However, these approaches require, as mentioned earlier, a certain level of expertise from the user.

On the semantic side, there is previous work on making entailments more intelligible by revealing only parts of the respective model in a user interactive fashion [7]. Other approaches suggest visualizations of DL concepts by models, where information that is irrelevant to the user is filtered [5]. In addition, there is previous work on computing minimal models for FOL [8]. Nonetheless, to the best of our knowledge, there is little research about transforming DL models respecting user definable properties.

5 Approach and Results to Date

Since DL models can be regarded as edge and vertex-labeled graphs, the initial formalism of choice is MSO transductions [9] which are a powerful tool to specify maps over graph structures using MSO formulae with free variables. Since many DLs admit the finite model property, decidability of these MSO formulae is non-critical. The definition of our model transformation framework is, however, not limited to MSO graph transductions. A well known alternative are, for instance, Graph Rewriting Systems [11].

In [13], we present a model transformation framework as described in Section 3 and define the basic decision problem of a *successful transformation*, meaning that a model transformation as an instance of the framework is called *successful* if and only if the image of the model transformation is indeed a model of the respective knowledge base that satisfies the additionally desired property. As an example of this framework, we construct a family of transformations for the DL $\mathcal{ALC}$ for obtaining finite tree-like models. We call the transformations ℓ-*unraveling*, where ℓ is a natural number determining the depth of the unraveling, and show that they are model-preserving. This is done by showing that any model and the transformations of it are bisimilar. We provide another use case of model transformations in [3, 4, 2], in which models are transformed in order to explain non-entailment for the DL $\mathcal{EL}$. The objective is to reduce counter examples for the non-entailment in question to a relevant minimum. Lastly, in a use case that does not have explanation as focus, we apply the model transformation techniques in [12] for repairing $\mathcal{EL}$ knowledge bases using methods from formal concept analysis [16].

6 Future Work

The first line of research is the extension of the catalogue of interesting properties for models that foster human understanding of knowledge bases and reasoning results. To support users of DL systems, findings from the cognitive sciences may be taken into consideration. Furthermore, user studies can be conducted to empirically verify the suitability of potentially interesting model properties.

The second direction of research is dedicated to the further investigation of the model transformation framework introduced in [13]. An open question in this context is if there can be an automated reasoning service that allows a user to specify a desired property for a model of a given knowledge base and deduces the MSO formulae that define the MSO transduction needed to transform the respective model. Future work will also consider model transformations with constants to incorporate reasoning services using named elements — foremost query answering over TBox and ABox. Since there are multiple formalisms to define model transformations, it is also reasonable to compare these formalisms with respect to their suitability for the overall task by, for instance, investigating their expressive power.

Acknowledgments This work has been supported by DFG in RTG 1763.

References

1. Alrabbaa, C., Baader, F., Borgwardt, S., Koopmann, P., Kovtunova, A.: Finding small proofs for description logic entailments: Theory and practice. In: Albert, E., Kovacs, L. (eds.) Proc. of the 23rd International Conference on Logic for Programming, Artificial Intelligence and Reasoning. EPiC Series in Computing, vol. 73, pp. 32–67. EasyChair (2020)

2. Alrabbaa, C., Hieke, W.: Explaining non-entailment by model transformation for the description logic $\mathcal{EL}$. In: Artale, A., Zhang, X., Calvanese, D., Wang, H. (eds.) Proc. of the 11th International Conference on Knowledge Graphs. ACM (2022), (to appear)
3. Alrabbaa, C., Hieke, W., Turhan, A.Y.: Counter model transformation for explaining non-subsumption in $\mathcal{EL}$. In: Beierle, C., Ragni, M., Stolzenburg, F., Thimm, M. (eds.) Proc. of the 7th Workshop on Formal and Cognitive Reasoning. CEUR Workshop Proceedings, vol. 2961, pp. 9–22. CEUR-WS.org (2021)
4. Alrabbaa, C., Hieke, W., Turhan, A.Y.: Relevant parts of counter models as explanations for $\mathcal{EL}$ non-subsumptions (extended abstract). In: Informal Proc. of the 2nd Workshop on Explainable Logic-Based Knowledge Representation (2021)
5. do Amaral, F.N., Martins, C.B.: Visualization of description logic models. In: Baader, F., Lutz, C., Motik, B. (eds.) Proc. of the 21st International Workshop on Description Logics. CEUR Workshop Proceedings, vol. 353. CEUR-WS.org (2008)
6. Baader, F., Peñaloza, R., Suntisrivaraporn, B.: Pinpointing in the description logic $\mathcal{EL}^+$. In: Hertzberg, J., Beetz, M., Englert, R. (eds.) Proc. of the 30th Annual German Conference on AI. Lecture Notes in Computer Science, vol. 4667, pp. 52–67. Springer (2007)
7. Bauer, J., Sattler, U., Parsia, B.: Explaining by example: Model exploration for ontology comprehension. In: Grau, B.C., Horrocks, I., Motik, B., Sattler, U. (eds.) Proc. of the 22nd International Workshop on Description Logics. CEUR Workshop Proceedings, vol. 477. CEUR-WS.org (2009)
8. Baumgartner, P., Fuchs, A., De Nivelle, H., Tinelli, C.: Computing finite models by reduction to function-free clause logic. Applied Logic **7**(1), 58–74 (2009)
9. Courcelle, B., Engelfriet, J.: Graph Structure and Monadic Second-Order Logic, Encyclopedia of Mathematics and its Applications, vol. 138. CUP (2012)
10. Dentler, K., Cornet, R., ten Teije, A., de Keizer, N.: Comparison of reasoners for large ontologies in the OWL 2 $\mathcal{EL}$ profile. Semantic Web **2**(2), 71–87 (2011)
11. Heckel, R.: Graph transformation in a nutshell. Electronic Notes in Theoretical Computer Science **148**(1), 187–198 (2006)
12. Hieke, W., Kriegel, F., Nuradiansyah, A.: Repairing $\mathcal{EL}$ TBoxes by means of countermodels obtained by model transformation. In: Homola, M., Ryzhikov, V., Schmidt, R.A. (eds.) Proc. of the 34th International Workshop on Description Logics. CEUR Workshop Proceedings, vol. 2954. CEUR-WS.org (2021)
13. Hieke, W., Turhan, A.Y.: Towards model transformation in description logics — Investigating the case of transductions. In: Beierle, C., Ragni, M., Stolzenburg, F., Thimm, M. (eds.) Proc. of the 6th Workshop on Formal and Cognitive Reasoning. CEUR Workshop Proceedings, vol. 2680, pp. 69–82. CEUR-WS.org (2020)
14. Horridge, M., Bail, S., Parsia, B., Sattler, U.: Toward cognitive support for OWL justifications. Knowledge-Based Systems **53**, 66–79 (2013)
15. Koopmann, P.: Two ways of explaining negative entailments in description logics using abduction. In: Informal Proc. of the 2nd Workshop on Explainable Logic-Based Knowledge Representation (2021)
16. Kriegel, F.: Constructing and Extending Description Logic Ontologies Using Methods of Formal Concept Analysis. Ph.D. thesis, TU Dresden (2019)
17. Schild, K.: A correspondence theory for terminological logics: Preliminary report. In: Mylopoulos, J., Reiter, R. (eds.) Proceedings of the 12th International Joint Conference on Artificial Intelligence. pp. 466–471. Morgan Kaufmann (1991)

Audio Speech Recognition in Noisy, Real-world Situations for Applications in Social Science

Darshit Pandya[1][0000−0003−4364−1185]

University of Mannheim

Abstract. The automatic analysis of topics discussed during family meals from audio recordings is relevant in social science research. However, Automatic Speech Recognition (ASR) for noisy, multi-speaker, real-world situations is still challenging, especially for non-English languages like German. The goal of this dissertation project is to alleviate these challenges, by investigating appropriate mitigating strategies for noisy audio, which can further aid in speaker diarization, and methods for topic analysis for social science research.

Keywords: ASR systems · noise · Social Science

1 Introduction

There has been a promising growth in the field of Audio Speech Recognition (ASR) in recent years. Performance metrics for ASR (primarily, Word Error Rate (WER)) has seen a significant drop [11], especially after the inception of End-to-End (E2E) ASR models. When it comes to English ASR systems, the research is now swiftly moving towards finer details (such as tackling regional accents, etc.). Unfortunately, the same cannot be said about ASR systems for other languages. Though the research and available datasets to improve them are gradually increasing, the performance (and applications) need some catching up to do.

Another challenge currently in ASR research is that of using these models in the wild (or in real life scenarios). Currently, many of the popular (non-English) ASR models (for instance, *German* ASR models available at [4]) are having difficulties dealing with real life data with ambient noise. This, in turn, creates a need for reliable (pre-processing) *Speech Enhancement (SE)* techniques to enhance its' performance, or modifications in model architecture to adapt to noisy speech [6]. In the specific context of Social Science research, the speech segments of interest mostly are recorded in a real-world scenario, and consequently is adulterated with ambient noise.

Thanks to the recent progress in Machine Learning (ML), the spectrum of ASR applications is quite wide. Even in *Social Science Research*, analysing audio signals has lead to some interesting pattern recognition of human activities. The work in [2] discusses one such application, where audio signals collected during family meal time have been used to derive different aspects of corresponding

activity, which in turn helps social scientists to establish/validate relations between family meal time participation and overall health of the participants. For applications in Social Science, it is essential for the ASR to figure out (at least) the topics being discussed from conversational speech signal.

In order to make a leap from ASR for clean audio to aiding in Social Science research specifically, there are many challenges. Starting from the audio data itself, the performance of ASR models depend largely on the quality of input audio. The closer the input audio is to the training data of the ASR model, the better the models' performance [12]. This PhD proposal intends to work towards examining the ASR systems' performance under real life situations, and trying to come up with mitigating strategies so that ASR system performance stay closer to the benchmarks, even for real-world, noise contaminated data. The current *CHiME challenge 6* [5] also considers this problem as follows: 'the problem of distant multi-microphone conversational speech diarisation and recognition in everyday home environment'. It is crucial to focus on the ***everyday home environment*** part, since it suggests the presence of noise found in everyday home environment (including audio from TV, sound from other household equipments, etc.), that can distort the original sound signal and influence ASR performance.

Staying with German ASR in Social Science research, there are many challenges, some of them are as follows

- Since social science research is not done on synthetic (clean) audio, it has to be done on real audio, it comes with real world noise (which already is an adopted challenge from ASR research as discussed above).
- The challenge with real-world noise is that one cannot necessarily generalise them. A classification of noise has to be done based on how they impact ASR performance.

2 Research Questions and Goals

The goal for my research is to mitigate the challenges described in the previous section, by investigating appropriate strategies to handle noisy audio, which could further be helpful in enhancing the performance of speaker diarization, and methods for extracting topics being discussed among family members during meal time. Broadly, the goal is to refine German ASR to facilitate real-world situations, by addressing the existing problems with ASR systems' robustness. In order to pursue and achieve this goal, I will have to seek solutions for the following research questions. This list is neither exhaustive nor explicit, it might get updated based on future results and its' inferences.

- How does different types of noise influence ASR performance?
- Is there a relation between ASR model architecture and its noise tolerance?
- What natural sources of noise can potentially impact ASR applications?
- How different is an ASR system's performance when it is subjected to data it is not trained to handle?

3 Related Work

The work [6] describes two general methods to tackle ambient noise for robust E2E ASR, namely *SE technique* and *E2E Model-based Adaptation*. It further explores different approaches for both methods. Another work [8] focuses on *Noise Reduction* techniques and provides a comparative study on the same. A relatively new approach is proposed in [7] where SE is performed using *Multi-Discriminators CycleGAN*. As mentioned in [7], there also exits another approach where a mapping network is trained that directly transforms the noisy features to the clean ones.

The recent work in [9] shows how ASR performance is affected by Noise Suppression Losses. When there are complex and sophisticated solutions to the problems of noise reduction and SE, they come with uninvited consequences of errors and signal loss. The work in [10] analyzes *the impact of SE errors on ASR*. They decompose SE errors into *Noise* and *Artifacts*, and conclude that while SE Noise does not really impact ASR performance that much, the artifact errors, defined as the SE error signal that cannot be represented as a linear combination of signal and noise, is *particularly detrimental* [10]. The work in [13] argues that the recorded low error rates for advance ASR systems would not hold true when subjected to real-world situations (including, and not limited to the acoustic environment).

4 Approach

The pipeline in Fig. 1 shows mandatory pre-processing audio processing steps to mitigate noise. The input, as discussed above is the real world, noisy audio. The ***Pre-processing and Data Cleaning*** step helps in preparing the input for further processing. As the name suggests, it cleans the input data so that the following model, in our case, ***German ASR model*** can perform at its best. The same cleaned data is also sent to the ***Speaker Diarisation*** module where we determine the number of speakers in the audio file, and when do they speak throughout the audio (for example, using a Deep Learning model). The output of the ASR model and the Diarisation module gives us a ***transcript***, which can then be used to perform ***Topical Analysis and Sentiment Analysis***, again in tandem with acoustic features from the cleaned audio.

Evidently, the current focus is on the *Pre-Processing* step and observing how noise impacts and influence different ASR model architecture. In pursuance of this, the planned steps and experiments are discussed in the following section 5. The future steps will be to focus on individual modules from the figure. For instance, experimenting with the idea of using Acoustic features and textual analysis of the transcript to perform Speech Sentiment Analysis.

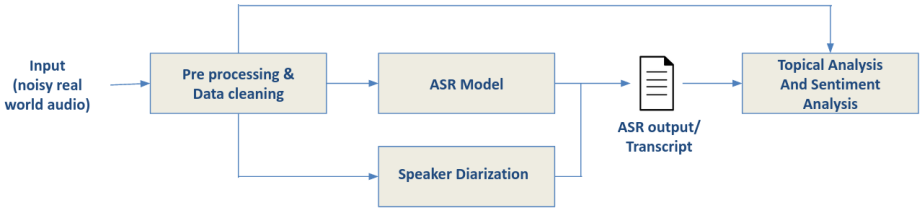

Fig. 1. Typical Pipeline for Social Science research using ASR

5 Evaluation

Because the range of applications for E2E ASR systems is too wide, one cannot assume that these systems are able to deal with every kind of noise. Instead of focusing on removing the noise from the audio data, we can try to pass the noisy audio data to different E2E ASR architectures (and its variants) and try to find the common denominator which deteriorates the performance of ASR models the most, and then we only have to focus on dealing with those specific types of noise. Naturally the way each ASR architecture deals with noise is based on many factors (including and not limited to the quality of training data, as discussed in [12]). The idea is to classify different types of noise, study how each of them impact the performance of different ASR models, and adapting the system to deal with that specific type of noise.

The evaluation strategy is planned as per the discussion above. Many of the deployable, complete state-of-the-art ASR solutions (especially for German) are trained with clean speech, and hence are required to be used with a SE module in the pre-processing step. The initial planned/proposed evaluation step is to adulterate clean datasets with different types of noise (for instance *Additive and Multiplicative Noise*), and then observe their impact on the models' performance. The *signal+noise* data can be tested on ASR models with varying SNRs and a threshold SNR can be found for each type of noise from which the ASR performance worsens. Usually, usage of a language model is recommended with ASR models so that they can predict more accurately. We can evaluate the ASR performance under noise along with a language model, to observe in case there is an improvement.

The following step will be to take a closer look at existing noise reduction and SE techniques and evaluate their performance based on how well do they tackle noise which impacts ASR performance the most. A mapping could be developed between ASR models/architectures getting impacted the most by a certain type of noise, and a corresponding noise reduction technique that handles that specific noise type the best. The output of noise reduction and ASR models working in tandem could then be evaluated by passing the output transcript through a benchmark topic detecting algorithm. A suitable performance metric could be explored which could state how clearly can we derive topics being

discussed during a conversation in real life using noise reduction/SE techniques, ASR model and a topic detection model. So, the proposed evaluation plan is to examine the performance of each module from Fig.1 individually, and then examining the modules in combination to get best end-to-end performance for real-life applications and research.

References

1. Polisetty S., Jenega S.: Applications of Speech Recognition in the Agriculture Sector: A Review. In: ECS Transactions, https://doi.org/10.1149/10701.19377ecst. Last accessed 18 July 2022
2. C. Bi et al., "FamilyLog: Monitoring Family Mealtime Activities by Mobile Devices", in IEEE Transactions on Mobile Computing, vol. 19, no. 8, pp. 1818-1830, 1 Aug. 2020, doi: 10.1109/TMC.2019.2916357.
3. Wang, Tianzi et al. "Conformer Based Elderly Speech Recognition System for Alzheimer's Disease Detection." (2022), doi: 10.48550/ARXIV.2206.13232, https://arxiv.org/abs/2206.13232 Last accessed 18 July 2022
4. Silero Team.: Silero Models: pre-trained enterprise-grade STT / TTS models and benchmarks. https://github.com/snakers4/silero-models Last accessed 18 July 2022
5. CHiME Challenge Homepage, https://chimechallenge.github.io/chime6/. Last accessed 18 July 2022
6. A. Prasad, P. Jyothi and R. Velmurugan, "An Investigation of End-to-End Models for Robust Speech Recognition", ICASSP 2021 - 2021 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2021, pp. 6893-6897, doi: 10.1109/ICASSP39728.2021.9414027.
7. C. -Y. Li and N. T. Vu, "Improving Speech Recognition on Noisy Speech via Speech Enhancement with Multi-Discriminators CycleGAN," 2021 IEEE Automatic Speech Recognition and Understanding Workshop (ASRU), 2021, pp. 830-836, doi: 10.1109/ASRU51503.2021.9688310.
8. K. Garg and G. Jain, "A comparative study of noise reduction techniques for automatic speech recognition systems," 2016 International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2016, pp. 2098-2103, doi: 10.1109/ICACCI.2016.7732361.
9. S. Braun and H. Gamper, "Effect of Noise Suppression Losses on Speech Distortion and ASR Performance," ICASSP 2022 - 2022 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2022, pp. 996-1000, doi: 10.1109/ICASSP43922.2022.9746489.
10. Iwamoto, K., Ochiai, T., Delcroix, M., Ikeshita, R., Sato, H., Araki, S., Katagiri, S, 2022. How Bad Are Artifacts?: Analyzing the Impact of Speech Enhancement Errors on ASR. https://arxiv.org/abs/2201.06685. Last accessed 20 July 2022
11. Li, Jinyu. "Recent advances in end-to-end automatic speech recognition." APSIPA Transactions on Signal and Information Processing 11.1 (2022).
12. Keung, P., Niu, W., Lu, Y., Salazar, J., Bhardwaj, V.. (2020). Attentional Speech Recognition Models Misbehave on Out-of-domain Utterances.
13. Alëna Aksënova, Daan van Esch, James Flynn, and Pavel Golik. 2021. How Might We Create Better Benchmarks for Speech Recognition?. In Proceedings of the 1st Workshop on Benchmarking: Past, Present and Future, pages 22–34, Online. Association for Computational Linguistics.

Towards improvement of company-related bankruptcy prediction models by expanding the training data base

Tobias Nießner[1]

[1] University of Goettingen, Göttingen, Germany

tobias.niessner@uni-goettingen.de

1 Introduction and Motivation

While a look at the bankruptcy figures of German companies over the past few years initially gives the impression that a falling trend can be observed, it is not only the possible bankruptcy delays as a result of the Covid-19 pandemic that show that, as the latest CreditReform semi-annual report from 2022 states, we have been able to observe a steadily negative correlation between the number of filed bankruptcies and the resulting loss amount for years. We are currently at more than double the level of bad debt losses per bankruptcy case compared to 2019 (in 2019 it was EUR 1.2 million and currently we are at EUR 2.6 million) according to CreditReform data (see Table 1).

Table 1. German bankruptcy informations from CreditReform

Year	Total cost damage	bad debts per bankruptcy case in EUR thousand	Total case number
2018	20,1	1,036	9.940
2019	23,5	1,248	9.690
2020	41,8	2,606	8.950
2021	54,0	3,822	7.510
2022 till June	19,0	2,603	7.300[1]

We can therefore assume that we will have to deal with a decreasing number of bankruptcies in the future, with the risk for stakeholders growing correspondingly stronger compared to the past. Regardless of this assumption, however, it is obvious that bankruptcy forecasting models must adapt to events in order to mitigate corresponding third-

[1] Estimation by CreditReform.

party damages resulting from unforeseen corporate bankruptcies by identifying them in advance. Classically, today's forecasting models in the field of bankruptcy forecasting are strongly based on the observation and analysis of quantitative financial ratios, which can be calculated and evaluated from balance sheet items. However, if we reflect on the last years of the Covid-19 pandemic, it becomes particularly clear that, for example, financial aid and the suspension of the bankruptcy obligation have led to a concealment of the financial situation, which is not recognizable through a classic view, as the corresponding financial ratios could be glossed over. Therefore, there is a great interest in research, but also in practice, in the improvement of the bankruptcy prognosis with the help of further data sources. The first source to be mentioned is the management report of a company, which has long been considered in manual analyses, but has had little influence on automated forecasting models. While financial ratios from the balance sheet have an information content limited to the past, it is also possible for companies to present outlooks and developments in the management report. As a result, we have to ask ourselves to what extent we can use this textual data in a meaningful way to improve our bankruptcy prognosis and, accordingly, also to evaluate the future in the form of decisions made or decisions still to be made by a company. In addition, the question arises as to what extent the financial situation of a company can be recognized in the future solely from the consideration of balance sheet items and whether characteristics describing the company structure with regard to the personnel structure and the industry affiliation, i.e. the resulting competitive pressure, are suitable for making the picture of the financial situation of a company explainable in more detail in combination.

2 Research Question

These considerations lead to the following central research question for my dissertation project:
How can company-oriented bankruptcy prediction models be improved by expanding the training database?

3 Related Work

In the following, we briefly review research in the area of qualitative AI-based corporate bankruptcy forecasting. The first thing to mention here is that most of the research was conducted based on 10K reports and thus differs linguistically in the analysis from the application area of German management reports. Reflecting on the research using Fromm et al.'s (2019) text mining feature taxonomy, it is clear that the majority of studies initially look at document-related features, with more recent studies suggesting that these, for example classic sentiment analysis of the text or metrics of the readability of a text, have much poorer correlations with the financial situation of a company than finer granular features within the text. A study from 2022 by Lohmann and Ohliger addresses this assumption and looks at the management report in its individual components, analyzing in detail the risk report alleading. Even an industry-specific classifi-

cation and reflection of the reports has so far not yielded any substantial results beyond the recognition of the industry using topic mining methods. In this respect, we have many open points of intersection to link up with the textual analysis of management reports, but also to connect external data sources that help us to gather further information about a company for evaluation. For more detailed considerations, I refer you to the related research considerations of my publications, which can be found in the CV[2].

4 Approach

Based on the Cross-Industry Standard Process for Data Mining, the function of my dissertation is to optimize the data understanding and data preparation phase. Within my studies published so far, I have been able to show various results regarding the similarity and comparability of consecutive financial statements and thus provided the first contributions dealing with a time series view of the change of linguistic features in text. Furthermore, I have an interest in the extraction of subject-specific features in text, which go beyond classical methods of text mining, since highly standardized, but also consecutively little changed, texts also push classical topic mining methods to their limits and insofar a creative subject-specific approach is needed.

5 (Planned) Evaluation

The planned evaluation of my studies is done in the context of my dissertation by applying my results to data preparation using ensemble learning methods, which are compared to selected basic models such as statistical randomness or classical quantitative models oriented by financial ratios. These choice for the use of ensemble learning methods is therefore based on a holistic view on the related research in bankruptcy prediction. However, the results will be compared to other algorithms too. Furthermore, an analysis of the weighting and discussion of individual training features is planned.

6 References

1. CreditReform Report, https://www.creditreform.de/fileadmin/user_upload/central_files/News/News_Wirtschaftsforschung/2022/Insolvenzen_in_Deutschland/2022-06-28_AY_OE_analyse_UE-halbjahr-2022.pdf, last accessed 2022/07/21.
2. Lohmann, C., Ohliger, T..: Bankruptcy Prediction and the discriminatory power of annual reports: empirical evidence from financially distressed German companies. Journal of Business Economics 90(1) (2020).
3. Fromm, H., Wambsganss, T., Söllner, M.: Towards a taxonomy of text mining features. European Conference on Information Systems 2019, (2019).

[2] https://www.uni-goettingen.de/de/627024.html