Rapid Explainability for Skill Description Learning

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Abstract

We tackle the problem of learning the description of skills of machines within an Industry 4.0 setting using Class Expression Learning (CEL). CEL deals with learning description logic concepts from an RDF knowledge base and input examples. The goal is to learn a concept that covers all positive examples while not covering any negative examples. Although state-of-the-art models have been successfully applied to tackle this problem, their application at large scale, e.g., for skill learning, have been severely hindered due to their impractical runtimes. We report on the initial results of the RAKI project jointly carried out by Paderborn University, Leipzig University, and Siemens AG. We designed a framework to facilitate CEL on large industrial RDF knowledge bases. Our framework learns concepts significantly faster than state-of-the-art models. Our verbalisation approaches ensure that our framework yields interpretable results. Our framework is open-source to foster large-scale applications.

Keywords

skill description learning, class expression learning, description logics

Within the Industry 4.0, smart factories and cyber-physical systems are tied to the promise of increased flexibility, adaptability, and transparency in production, thus increasing the autonomy of machines. One such manufacturing process is skill matching, where operations in a production process are assigned to machines. A prerequisite for this technology are skill descriptions of the machines and skill requirements of the operations [1]. In some cases, skill descriptions are only partially available or not available at all. Defining and digitizing skill descriptions of a production module are typically done manually by domain experts in a time- and resource-intensive process. **Objectives:** Our main aim is to efficiently automatize the skill description learning problem. Given that skills can be encoded as OWL class expressions, addressing this challenge can be mapped to a CEL problem [2]. This form of ante-hoc explainable Artificial Intelligence (AI) (XAI) is well suited for skill learning, as class expressions are interpretable—e.g., through verbalisation techniques [3]—and, a lack of transparency and explainability in AI would reduce the acceptance of the skill descriptions learned automatically [4]. However, successful large-scale industrial applications of CEL models have not yet taken place. Arguably, this stems from the impractical runtimes of CEL models due to their reliance of fixed myopic heuristic functions and

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not utilizing parallelism. We hence rely on a framework that reduces the impractical runtimes of classical CEL approaches so that CEL can be carried out on large RDF knowledge bases. The framework includes a verbalisation module to decrease the amount of AI expertise necessary to interpret results of CEL problems, e.g. predictions are interpretable even by novice practitioners.

Solution: We designed the RAKI framework (https://github.com/dice-group/DRILL_RAKI) is based on inductive logic programming, deep reinforcement learning and verbalisation modules. We designed a model (DRILL) based on deep Q-Network model to significantly decrease the impractical runtimes [5]. This is achieved by replacing a fixed myopic heuristic function with a learned Q-function that incorporates future considerations in immediate actions. In the RAKI framework, knowledge graph embeddings can be easily learned to train DRILL [6, 7]. The verbalisation module translates a learned class expression into sentences.

Results & Business value: The RAKI framework was evaluated on learning problems from the skill description use case. The results show that our framework yields the best performance with respect to accuracy and F1-score, and that it can also learn class expressions that describe the positive and negative examples in the learning problem more precisely than state-of-the-art baselines. In particular, the integration of domain knowledge by excluding previously defined concepts leads to non-trivial and thus more useful class expressions. Especially the high scalability of the framework allowed the calculation of results in a short time, while the second-fastest baseline needed approximately 8 times as long on this use case. Moreover, the verbalization of the class expressions to natural language made it easier for the plant operators to understand the skill descriptions, facilitating the subsequent skill matching step. Automatizing the skill description learning problem reduces personnel expenses since a skill description of a production module can be learned without a domain expert. Moreover, the verbalisation module saves time of domain experts, as learned descriptions can be interpreted easily. Importantly, the ability of tackling this problem efficiently allows us to fully utilize large RDF knowledge bases[1].

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