Ontological Modeling and Reasoning for Comparison and Contrastive Narration of Robot Plans

Extended Abstract

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ABSTRACT

This extended abstract focuses on an approach to modeling and reasoning about the comparison of competing plans, so that robots can later explain the divergent result. First, the need for a novel ontological model that empowers robots to formalize and reason about plan divergences is identified. Then, a new ontological theory is proposed to facilitate the classification of plans (e.g., the shortest, the safest, the closest to human preferences, etc.). Finally, the limitations of a baseline algorithm for ontology-based explanatory narration are examined, and a novel algorithm is introduced to leverage the divergent knowledge between plans, enabling the construction of contrastive narratives. An empirical evaluation is conducted to assess the quality of the explanations provided by the proposed algorithm, which outperforms the baseline method.

KEYWORDS

Ontology; Reasoning; Robotics; Contrastive explainable agency

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1 INTRODUCTION

Autonomous artificial decision-making in environments with different agents (e.g., robots collaborating with or assisting humans) is complex to model. This is often due to the high degree of uncertainty and potential lack of communication among agents. For instance, robots might need to choose between competing plans, comparing their properties and deciding which one is better. This might happen when a human gives an ambiguous command (e.g. 'can you bring me a drink?'), thus the robot may find different plans to achieve the abstract command (such as bringing any of the available drinks). Then it would be necessary to compare and disambiguate the plans (see Fig. 1). In these cases, mutual understanding of the ongoing decisions and communication between agents become crucial [13]. Hence, trustworthy robots shall be able to model their plans' properties to make sound decisions when contrasting them. Furthermore, they shall also be capable of narrating (explaining) the knowledge acquired from the comparison. Note that robots add the possibility of physically executing the plan, which may affect the human, strongly motivating the need for explanations, which may serve two purposes: justifying the robot's selection of a plan, or asking the human to help in the disambiguation.

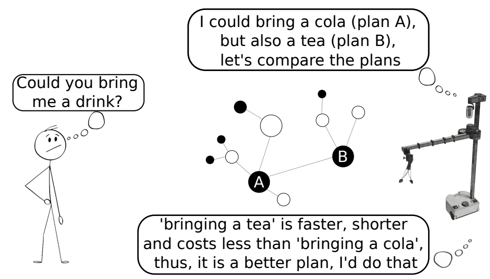

Figure 1: A prototypical scenario where a robot contrasts two plans and reasons about which plan is better to execute.

Concerning the modeling of domain knowledge for reasoning, a common approach is to use sound formalisms such as ontologies. The literature shows that multiple ontologies have been lately developed and even standardized for different robotic applications and domains [3, 5, 9, 12]. Furthermore, several works have investigated how narrating or verbalizing robots' internal knowledge (e.g. a plan's sequence) could boost explainable agency (i.e., explaining the reasoning of goal-driven agents and robots) [2, 4, 11]. Olivares-Alarcos et al. [8], proposed a methodology for the construction of explanatory ontology-based narratives for collaborative robotics and adaptation (XONCRA). It consisted of a knowledge base for

Proc. of the 23rd International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2024), N. Alechina, V. Dignum, M. Dastani, J.S. Sichman (eds.), May 6 – 10, 2024, Auckland, New Zealand. © 2024 International Foundation for Autonomous Agents and Multiagent Systems (www.ifaamas.org).

collaborative robotics and adaptation (know-cra), and an algorithm to generate explanatory narratives using experiential knowledge (AXON). One might wonder whether the XONCRA methodology could be used to model and narrate the divergences between plans. Indeed, XONCRA uses an ontology named OCRA [10] that defined the relationship 'is better plan than', associating two plans denoting that one of the plans is considered to be better. However, the authors did not model in OCRA how an agent might find divergences between two plans and decide which one is better. Hence, it is necessary to propose a new theory for plan comparison. Moreover, while being a potential baseline solution, the narratives generated by AXON were not optimized for a contrastive case as the one that concerns this work, and a better approach shall be investigated. Hence, it is proposed to address the following research questions:

- **RQ1 -** How could robots model and reason about what differentiates (two) plans, making one better?
- **RQ2 -** How could robots leverage the proposed ontological model to explain (narrate) what differentiates (two) plans?

2 MODEL FOR ROBOT PLAN COMPARISON

A novel model is needed to formalize the ontological classes and relationships to represent knowledge and reason about plans and their characteristics for plan comparison and contrastive narration. In order to scope the subject domain to be represented in the model, a set of competency questions is proposed, which are a set of requirements on the ontology content. Specifically, the proposed ontological model is expected to be able to answer the following questions:

- **CQ1 -** Which are the characteristics of a plan?
- **CQ2 -** How do the characteristics of different plans relate?
- **CQ3 -** How do different plans relate to each other?

The new model is built upon OCRA, re-utilizing the existing model and extending it. Therefore, OCRA's upper ontology is inherited, the DOLCE+DnS Ultralite (DUL) foundational ontology [1]. For practical use, the proposed theory is formalized in OWL 2 DL.

3 CONTRASTIVE NARRATIVES OF PLANS

3.1 Can explanatory narratives do the work?

Using the new ontological model and the XONCRA methodology [8] might seem to be enough to narrate what robots know about competing plans. In particular, given the episodic knowledge about two plan instances and how they relate, a narrative about each of the plans could be constructed using the algorithm AXON. The two narratives together would probably include the relevant knowledge for a robot to infer which plan is better, thus, humans could read the narratives and understand the inference. The differences between the two narratives could even be highlighted, as others have done when contrastively explaining the traces of two plans [6]. However, such an approach would still require humans to extract their own conclusions by reading the complete narratives. Therefore, while being a potential baseline solution, such narratives do not seem to be optimized for the cases that concern this extended abstract, and a better approach might be developed.

3.2 Beyond plain explanatory narratives

Miller [7] stated that explanations are *contrastive*, *selected*, and *social*. Contrastive because they are sought in response to counterfactual cases that open questions such as: why a plan is better instead of others. Explanations are selected as they usually contain just part of the reasons, extracted by agents from a larger knowledge and based on specific criteria. Finally, explanations transfer knowledge in a conversational format, being part of a social interaction between agents. These three aspects of explanations set the basis to design a better algorithm, an alternative to the baseline AXON that:

- constructs contrastive narratives instead of plain narratives;
- enhances the selection of knowledge, extracting only the differences between the compared plans; and
- reduces the time needed to communicate a narrative, aiming to enhance (social) interaction.

Hence, a novel algorithm is proposed that leverages knowledge about divergences between ontological entities (e.g. plans) to construct contrastive explanatory narratives. The focus here is on narratives about *Plans*, but the algorithm is general enough to work with other OWL 2 DL classes. For instance, it might contrastively narrate the capabilities of two robots (e.g. one can carry heavier payloads), or how two drinks differ (e.g. one is healthier).

4 CONCLUSION

This work discusses a method for robots to model and reason about the differences between plans, to infer which one is better and to narrate the inferences to other agents (e.g. humans). The approach comprises a novel ontological model for robots to describe plans and their qualities and compare them, and a new algorithm to construct ontology-based contrastive explanatory narratives. Both are general to be used with other ontologies, beyond the case of contrasting plans (e.g. modeling the qualities of two drinks and narrating the differences). The model is validated by instantiating it to answer a set of competency questions. The algorithm is evaluated against a baseline with respect to a set of objective metrics. The proposed approach outperforms the baseline in general, doing a better selection of knowledge tuples to build the explanation (avoiding non-divergent knowledge), and producing explanations that would require less time for the robot to communicate them. Details about the method, and its evaluation are available online.[1]

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