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The Fourth Summer School on Argumentation: Computational and Linguistic Perspectives (SSA 2020)

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Preface

This volume includes the thesis abstracts presented at the Fourth Summer School on Argumentation: Computational and Linguistic Perspectives (SSA 2020), held on September 4-8 fully online due to the persisting coronavirus crisis. It was the fourth event in the series of Summer Schools on Argumentation, the first Summer School on Argumentation took place at the University of Dundee in 2014 in the UK, the second took place at the University of Postdam in 2016 in Germany, and the third at the Warsaw University of Technology in Poland.
The main aim of SSA 2020 was to provide attendees with a solid foundation in computational and linguistic aspects of argumentation along different perspectives (abstract and structured level, argumentation as inference and argumentation as dialogues, probabilistic argumentation, argument mining and application of argumentation for normative and legal reasoning) and the emerging connections between the two. Furthermore, attendees gained experience in using various tools for argument analysis and processing.
This collection comprises the thesis abstracts submitted by participants of the student program of SSA 2020 which consisted of a poster session, where participants could present their work and discuss it with the lecturers and keynote speakers, and a mentoring session, where topics related to their research were discussed.

August 2020

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Argument Mining on online comments

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1. Introduction

The main goal of this PhD project (started in October 2018, running until October 2022) is to develop a system for the automatic detection of argument structures (components and relations) from user-generated reply texts (part of User Generated Content (UGC)) found on social media. I am interested in mining argument structures from natural language online. This data has been studied in Natural Language Processing (NLP) in relation to the detection of topics, stance, sentiment and emotion [1]. Despite the importance of these research fields, the more recent field of argumentation mining can help extract information of a more fine-grained nature, enriching the findings of these fields [2].

I want to study argumentation in its natural context, expanding argumentation theory to include less formalized domains like UGC. This will help further on of the aims of Argumentation Theory, which is to study argumentation in a non-artificial way, with examples from practical, natural contexts [3]. If we can automatically detect the reasons underlying political opinions expressed by users online, we come closer to mapping the connections between various political issues and to identifying some of the reasons behind the breach between "official" politics and people's idea of what politics could and should achieve.

2. Objectives

This project takes a *product-oriented* view on argumentation [4], which means the analysis will always start from what is expressed in the text (the product). We believe the identification of certain types of linguistic expressions (like irony or rhetorical questions) in the *product* (e.g., the argumentative comment to a Facebook post) will provide the necessary inroads for studying part of the *process* of the argumentation, which often relates to implicit meanings. It is our goal to work on incorporating existing insights from the field of Linguistics (such as Relevance Theory [5] within cognitive linguistics and pragmatics) surrounding such forms of implicit expressions to help inform our argument analysis. Currently, an extensive reading of literature surrounding the vast field of Argumentation Theory spanning different disciplines is ongoing. Since the automatic detection of argument structure is a task of considerable complexity, the focus will shift away from related tasks which typically precede the tasks of argumentation mining proper, such as topic and stance detection. Existing approaches

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will be employed for both topic and stance detection, but the various subtasks of argumentation mining (claim and reason detection, support/attack relation detection, counterconsideration detection, enthymeme resolution) will be our main focus.

In order to classify arguments according to their content and to be able to identify the various components of the argument, it is important to use a well-developed argument framework to guide the analysis. Such a framework has to be based both on theoretical insights from conceptual argumentation studies (for example, from the field of Informal Logic) as well as empirical research performed on argumentative text data (which can be found in disciplines like pragmatics (e.g., [6]) and cognitive linguistics and related fields (e.g., [7]). Many approaches exist for the analysis of argumentation on various types of text genres (such as legal argumentative texts, scientific writing, political debates, etc. [8]). No consensus has been reached yet about which argument analysis approach might be best suited for the use case of argumentative online user-generated comments on social media platforms [8].

This project aims to develop a set of annotation guidelines capable of annotating argumentation in argumentative user comments. I have performed a pilot annotation study on a sample corpus of 100 Dutch comments sourced from the Facebook page of a well-known Flemish newspaper. The aim of this first annotation study, currently under review, is to test the suitability of our current guidelines for the tasks of topic, stance, argumentativeness and claim annotations on user-generated reply texts. The results from this pilot study will serve to improve the guidelines to serve as the basis for a new annotation study on a larger corpus of comments, which will in turn serve as training data for the automatic detection of argumentative structure in user-generated comments. This second annotation study will also include the tasks of premise and relation detection. We therefore aim to take a global approach to the various tasks of argumentation mining, following [9], as we believe many of the tasks are dependent on each other.

The corpus consists of Dutch reply texts, since the non-English corpora for argumentation mining for this type of data are currently quite limited (Greek [10] and German [9] being the only ones currently available to our knowledge). The Facebook corpus is an important addition since this platform tends to be underrepresented in NLP research on automatic detection tasks, because of the difficulties in data collection. Given the popularity of this platform as a source of news for many users [11], it is essential to take it into account when attempting to uncover opinions on current events online.

The pilot annotation study currently under review is part of the preparations I am currently working on for conducting an annotation study on a corpus of 6,000 Dutch argumentative comments sourced from Twitter, Facebook and online newspapers. All the comments are made in response to a newspaper article on a political topic (e.g., poverty reduction efforts made by the government, reception of corona measures etc.). For the topic annotations, I employ the distinction between structuring and interactional topics as developed by [12], since this approach was used successfully by [11] on very similar data. Next, the stance will be annotated for each comment. The third step is the segmentation of the comments into their argumentatively relevant constituent parts. The fourth step consists of the annotation of the actual argumentation contained in the comments. This step will be performed by me and two additional student annotators who will be trained with the same guidelines for the annotation of claims, reasons (supporting and attack) and counterconsiderations. This annotation study will give us the labelled training and test data which is needed to develop our machine learning system for the automatic detection of claims, reasons and support/attack relations in unseen user comments. I aim for initial experiments with this data around October.

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Conversational Agents based on Argumentation Theory and Ontologies

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Abstract. We aim to develop an approach to support the development of dialogue systems based on BDI (Belief-Desire-Intention) agents to assist humans in decision making. The approach uses Argumentation Theory and Ontology techniques as the basis for dialogues in natural language. The goal is to make our approach adaptable enough that it can be applied across multiple domains. To evaluate our approach, we intended to create an agent-based system to support bed allocation that can be adopted in public hospitals in Brazil, and an agent-based system to be adopted in the Brazilian judicial system to accelerate the processing of lawsuits related to council taxes.

Keywords. Dialogue systems, Argumentation theory, Ontology

This research focuses on combining Argumentation Theory and Ontology techniques to support complex dialogues in natural language. In particular, we aim to create an approach to support the development of dialogue systems that take advantage of that combination of techniques within BDI (Belief-Desire-Intention) agents to assist humans in decision making. Our goal is to make this approach adaptable enough that it can be applied across multiple domains. We are particularly interested in applying our approach to healthcare and law domains.

Both areas can benefit from a decision support system. In the health area, bed allocation represents a challenge to hospitals (especially in developing countries, such as Brazil) because hospital beds are a scarce resource. Also, hospital environments are highly dynamic and uncertain, so allocating hospital beds optimally plays an essential role in the overall planning of hospital resources [1]. Thus, it would be interesting a system that assists in suggesting better bed allocations for the professional responsible for this task.

Another area we are interested in is tax law. Tax enforcement processes, for example, represents 75% of the total of enforcement processes in the judicial system in Brazil. These processes are primarily responsible for the high congestion rate in the judiciary, as they represent approximately 38% of the total pending cases in Brazil [2]. This large volume of overdue lawsuits hinders the effectiveness of justice. In this way, systems developed using Artificial Intelligence techniques can help to simplify the processing of lawsuits.

Moreover, we chose these two domains, because both are known to have a certain resistance to the replacement of human operators by automated systems. This is understandable because both areas deal with human lives or rights, in the sense that a wrong

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decision by an automated system can seriously impact people's lives. That is why it is important to have a system that assists in decision making, but that the human operator makes the final decision. Another important challenge is maintaining and increasing the user's willingness to interact with the technical system [3]. In these cases, a mixed initiative system, which supports human-computer interaction, becomes useful [4].

Thus, we believe that the use of dialogues in natural language facilitates the interaction and adaptation of human operators. Also, the use of argumentation theory and ontology can make this dialogue more useful for the user. The argumentation ability provides to agents more autonomy and smarter behaviour [5]. Ontology, on the other hand, helps the agent to organise domain knowledge, containing all relevant entities and their relationships [6] providing the possibility of ontological reasoning about the domain.

Motivated by the presented context, we identified the following research objective: *Investigate how argumentation theory and ontology techniques can be used together with reasoning about intentions to build complex natural language dialogues to support human decision making.*

Our first step in that direction was to investigate the health and law domains. For that, we count on the help of specialists from both areas. So far we have built two ontologies. The first, in the law domain, contains concepts from the area of tax law in Brazil. This ontology contains 98 concepts ranging from basic concepts of law, such as the meaning of the word "Law" to more specific concepts, such as "Tax jurisdiction" and "Tribute" [7]. The second ontology is in the healthcare domain, specifically hospital bed allocation, which contains 95 concepts related to patient attendance, risk classification, health state, among others [8].

Also, in our previous research [9], we interviewed professionals responsible for hospital bed allocation and obtained the bed allocation rules. Then, we created a BDI agent to aid bed allocation; this agent performs a bed allocation plan using a planning domain built on the allocation rules. We identified some improvements for future work, such as our agent in addition to saying which rules were broken, also making suggestions about bed allocations. We believe that with the use of argumentation theory and ontology techniques, our agent will be able to reason about beds and patients' relations, thus making *explainable* suggestions to help the professionals perform a better bed allocation.

In the next steps of our research, we will integrate the constructed ontologies with the BDI agent. We are also in the process of formalising argumentation-based dialogues that can switch from domain-specific facts to ontology issues (such as whether an individual effectively belongs to a certain class) related to that same domain. After implementing the approach, we will develop the two proposed conversational agents, which will be evaluated by domain experts in Health and Law. For the Law agent, it may be necessary to extract argumentation schemes from documents using machine learning techniques for argument mining. We are starting research on available techniques in the literature to support that part of our dialogue system.

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Economic Rationality as an Argumentation Principle[1]

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1. Introduction

Formal argumentation approaches have gained popularity in the symbolic artificial intelligence community as methods of non-monotonic reasoning. A particularly popular variant is abstract argumentation [1], in which an argumentation framework is a tuple that consists of a set of propositional atoms ("arguments", *e.g.*, $\{a,b\}$) and a binary relation on this set that denotes *attacks* (*e.g.*, $\{(a,b)\}$ denotes that a attacks b). One research direction in the field of formal argumentation is the design and evaluation of *argumentation semantics*, *i.e.*, functions that determine which nodes in a graph of arguments can be considered valid conclusions. For example, depending on the argumentation semantics (denoted by σ), the conclusion from the argumentation framework $AF = (Arguments, Attacks) = (\{a,b,c\}, \{(a,b),(b,c),(c,a)\})$ can be resolved as $\sigma(AF) = \{\{\}\}$ (the empty set is a valid conclusion) or $\sigma(AF) = \{\{a\},\{b\},\{c\}\}$ (either $\{a\}$, or $\{b\}$, or $\{c\}$ is a valid conclusion). Each item in the set of sets an argumentation semantics returns is called an *extension*. For example, given AF as introduced above and given $\sigma(AF) = \{\{a\},\{b\},\{c\}\}$, $\{a\}$ is a σ-extension of AF. To support the formal analysis of the behavior of argumentation semantics, *argumentation principles* have been defined [2]. A principle can, for example, stipulate that given any argumentation framework, a semantics must return at least one extension. To provide a novel perspective on argumentation semantics and principles, we define the new *reference independence* principle that is based on a formal model of economic rationality. Considering the influence of economic rationality on ground-breaking decision-theoretical (and game-theoretical) research such as the Nash equilibrium and Tversky's and Kahneman's work on bounded rationality [3], we assume that the same model can be useful in the context of formal argumentation as a collection of methods for *deciding* which arguments in an argumentation framework can be considered valid conclusions.

2. Economically Rational Argumentation: The Reference Independence Principle

Economic rationality as a formal property is one of the cornerstones of microeconomic theory. Given a set S, and a decision-maker's choice $A^* \subseteq S$, economic rationality assumes that the choice implies the decision-maker's preference $\forall A \subseteq S, A^* \succeq A'$, *i.e.*, A^* is preferred over all other possible choice options. It follows that given a set $S' \supseteq S$, and a decision $A^{'*} \subseteq S'$, it needs to hold true that $A^{'*} \not\subseteq S$ or $A^{'*} = A^*$; otherwise the pref-

[1] The author thanks Dov Gabbay and Juan Carlos Nieves. This work was supported by the Wallenberg AI, Autonomous Systems and Software Program (WASP) funded by the Knut and Alice Wallenberg Foundation.

erences implied by the choice of $A^{'*}$ from S' are inconsistent with the preferences implied by the choice of A^* from S (see, for example Rubinstein [4]). This property is often referred to as *reference independence* and can be adjusted to be applicable to abstract argumentation[2], which we can illustrate by example. Let us assume we have a consultant who should recommend whether a product is to be launched or not. When starting her analysis, the consultant finds no reasons for not launching the product, *i.e.*, she constructs the argumentation framework $AF = (\{l_p\}, \{\})$, where l_p stands for "launch product", and we assume she determines $\{l_p\}$ as the only extension of AF. However, after talking to the decision-makers, the consultant is instructed to gather more thorough stakeholder feedback that argues for or against (directly or indirectly) launching the product. After gathering the feedback, she ends up with the argumentation framework $AF' = (\{l_p, a, b, c\}, \{(a,b), (b,c), (c,a), (c,l_p)\})$. Let us note that AF' is a *normal expansion* of AF, *i.e.*, AF' contains all arguments and attacks of AF and no new attacks are added between arguments that exist in AF (colloquially speaking). Yet, many argumentation semantics determine that $\{\}$ is the only extension of AF', which means although our consultant does not consider any reason against launching the product a valid conclusion, she no longer recommends launching the product. This is not economically rational, and also questionable from a common-sense perspective, assuming that the decision-maker would like to have a valid reason for not launching.

3. Research Directions

The reference independence principle can provide the foundation of a new line of research on formal argumentation that investigates the following phenomena, for example:

- It can be considered desirable to be able to select a semantics' extension of an argumentation framework, add new arguments to the framework and to ensure that the extension we select from the new argumentation framework is consistent (from an economic rationality perspective) with the previous extension we have selected. Assuming that in abstract argumentation, inconsistent preferences are caused by cycles (or: "loops") in argumentation frameworks (see: [5]) "loop-busting" approaches, as presented by Gabbay [6] can be employed.
- Economic rationality in strategic scenarios (with several, potentially adversarial agents) is a cornerstone of game theory. Consequently, it can be assumed that having a formal argumentation principle of economic rationality can provide new interesting perspectives on works on game theory and formal argumentation, as for example presented by Rahwan and Larson [7].
- In many popular argumentation approaches, arguments are not always either in an extension or out, but can have other values, such as "undecided" [8]. While indecisiveness is not well-aligned with economic rationality, adjusting the reference independence principle to many-valued argumentation approaches can create interesting capabilities. *E.g.*, an agent may be allowed to consider an argument *undecided* iff this arguments does not model an action or utilitarian preference.

From a practical perspective, reference independent argumentation can help ensure the consistency of inferences made by decision support and automation systems, for example of argumentation-based dialog systems [9].

[2] See ongoing work reported in [5].

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Approximate Reasoning with Abstract Argumentation Frameworks using Artificial Neural Networks

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Keywords. reasoning, abstract argumentation, neural networks, deep learning

1. Introduction

Computational models of argumentation are methods for non-monotonic reasoning that focus on the interplay between arguments and counterarguments in order to reach conclusions. *Abstract* argumentation encompasses the classical abstract argumentation frameworks following Dung [5], where argumentation scenarios are represented as directed graphs. In these graphs, vertices represent arguments and edges represent attacks between such arguments. Formally, an abstract argumentation framework AF is a tuple $(\mathsf{Arg}, \rightarrow)$ where Arg denotes a set of arguments, and $\rightarrow \subseteq \mathsf{Arg} \times \mathsf{Arg}$ denotes an attack relation. In the context of such abstract argumentation frameworks, it is usually of interest to identify extensions, i.e., sets of arguments that are mutually acceptable and thus provide a coherent perspective on an outcome of the argumentation.

2. Motivation

Determining the set of acceptable arguments regarding certain semantics is complexity-wise a hard task. For instance, the problem of credulous acceptance under a given semantics, i.e., the problem of deciding whether a given argument in an AF is acceptable under such semantics, is NP-complete [7]. Consequently, there is a need for practically feasible methods to deal with such problems. Approximate reasoning approaches present a great potential for comparatively short runtimes. This is shown in [9,4,11], where artificial neural networks are utilized as a black-box method for approximation. However, the short runtime comes at the price of accuracy. Thus, the requirement for fast execution is complemented by that of high accuracy. Although approximate techniques might not be adequate to replace exact ones in certain use cases, they could still be used as a heuristic which facilitates the achievement of shorter runtimes of exact approaches. Furthermore, the two fields of machine learning and reasoning/knowledge representation have mostly been regarded separately. They mostly serve different applications and exhibit different strengths and weaknesses. Hence, finding techniques to combine these two areas could be useful to overcome their respective limitations.

3. Related Work

Previous works on reasoning with abstract argumentation mostly focus on sound and complete approaches. However, the potential of approximate methods should be considered as well, since they tend to be much faster. In [9], we trained a graph convolutional network (GCN) [8] to decide whether or not arguments are included in a preferred extension. The runtime could be drastically improved, compared to the sound and complete CoQuiAAS [10] solver while keeping the accuracy at around 80%. More specifically, CoQuiAAS needed about an hour (60.98 minutes) to process a test set, while the GCN approach took < 0.5 seconds. This preliminary study shows that neural networks seem generally capable of capturing features of certain semantics regarding abstract argumentation.

Malmqvist et al. [11] extend the previously described work [9] by proposing a randomized training technique for GCNs. This novel training technique is complemented by a dynamic balancing of training data, as well as adapted residual connections. The authors report accuracy values of up to 97.15%.

Craandijk and Bex [4] introduce an argumentation graph neural network (AGNN) which predicts the likelihood of an argument being accepted under multiple semantics by learning a message-passing algorithm. The authors consider both credulous and skeptical acceptance. As opposed to the previously mentioned GCN, the proposed neural network architecture is of recurrent nature. Overall, the AGNN method outperforms the GCN method described in [9].

4. Approach

The aim of the thesis is to continue and expand on the existing works on the topic of approximate reasoning. We focus on the exploration of different neural network architectures combined with different types of semantics, such as Dung's originally proposed complete, grounded, stable, and preferred semantics [5]. The literature offers a variety of additional semantics that could be contemplated. Examples are semi-stable [2], ideal [6], or eager [3] semantics. Moreover, the approach could be applied to semantics based on weak admissibility and weak defense, as introduced in the recent work by Baumann et al. [1].

Although the focus of the thesis is on neural network-based techniques, using other approximation methods than neural networks is also an aspect that could be worth considering.

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A Hybrid Agent Architecture for Inquiry at the Dutch National Police

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Conversational agents or dialogue systems are agents that converse with other agents. In my dissertation research, I study agents for *inquiry dialogue*, which collaborate with each other or with a human user in order to find evidence for (or against) a given claim [12]. These agents have practical applications for organisations that need to be well-informed in order to evaluate claims, such as the Dutch National Police. The police receives a large amount of messages, typically in unstructured free text, that need to be tested against some claim. For example, in reports concerning online trade fraud, the claim would be that the citizen reporting the crime is likely to be a victim of fraud. Our project Intelligence Amplification for Cybercrime [2] aims to study and develop artificial intelligence (AI) agents that assist in processing these messages. To this end, our agents are required to acquire complete information by consulting external sources, such as the citizens reporting a crime, databases or human operators at the police.

Agents for inquiry in the legal or law-enforcement domain have some specific requirements, as I identified in [1]. These agents should *accurately* and *efficiently* find the status of the claim under discussion, responding to *natural language input* by asking *relevant* questions or by drawing *explainable* conclusions. None of the existing methods from (machine-learning based) conversational AI [3] or formal argumentation dialogue [5] meets all of these requirements. However, they have some interesting properties that can be used in a hybrid system: it is common to use machine learning techniques for *handling natural language*; argumentation techniques can be applied to enable *transparent* and *accurate* decision-making and to ask *relevant* questions; and reinforcement learning techniques can be used to create an *efficient* dialogue. In my dissertation research, I explore the possibilities of combining these approaches.

We proposed an architecture of a hybrid agent in [8,10]. The architecture consists of an information extraction, argumentation and policy learning component and is illustrated in Figure 1. The **information extraction** component extracts observations from free text user input (*handling natural language*). The **argumentation** component reasons with these observations, based on its underlying argumentation setting [6], which consists of a logical language and a predefined set of rules. Thanks to our STABILITY algorithm, introduced in [11] and improved in [4], the agent can infer if any observable propositions can still change the acceptability status of the main claim. In many cases, there will be multiple of these *relevant* propositions. The **question policy** component is optimised to find the best question to ask for any combination of observations (*effi-*

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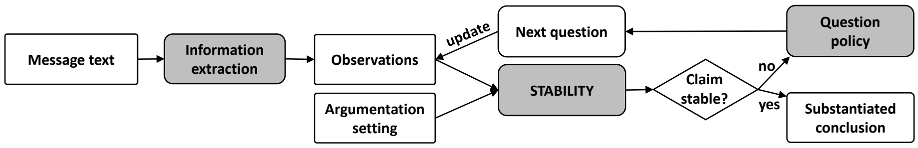

Figure 1. *Overview of the hybrid inquiry agent.*

ciency). Once no observable proposition is relevant, the dialogue terminates. By validating the argumentation setting with domain experts, we can guarantee that the outcome of the dialogue is *accurate*. Finally, *transparency* can be obtained by explaining why arguments supporting or attacking the main claim should, or should not, be accepted.

An instance of our agent architecture is in production on the web site of the Dutch Police[2]. Since its release in September 2019, it has handled the intake of tens of thousands of reports on online trade fraud. This application can be considered successful as it meets our requirements; however, to be able to implement and study more complex instantiations, we addressed, or plan to address, five research questions:

Q1 How to extract information from messages in an accurate and transparent way?
Q2 How to efficiently determine whether the dialogue should terminate?
Q3 How to efficiently select literals that are still relevant?
Q4 How to make sure that the dialogue is coherent, while still optimising efficiency?
Q5 How to explain the outcome of the dialogue?

Until now, my research mainly focused on Q2. In [11], we introduced the dynamic argumentation task of detecting stability: given a specific structured argumentation setting, can adding information change the acceptability status of some propositional formula? As we proved in [4], accurately detecting stability is not tractable for every input. In [4], we presented a sound approximation algorithm that recognises stability for many inputs in polynomial time and showed under which constraints on the input our algorithm is complete. This algorithm is an improvement on our earlier algorithm published in [11].

Question Q1 relates to the information extraction component. Although it was shown in [9,7] that machine learning techniques can be used to perform information extraction, these techniques have serious drawbacks in practice: they require labelling large amounts of data and typically result in opaque models. Instead, we currently use regular expressions to construct classifiers for the fraud application, but this requires manual modelling. We plan to investigate if we can combine machine learning and regular expressions to construct a hybrid classifier for transparent and accurate information extraction.

Regarding Q3, the fraud agent contains a relevance listing algorithm that returns the literals that are still relevant for the acceptability status of a given (unstable) claim. We plan to analyse this algorithm in terms of soundness, completeness and complexity.

Q4 concerns the question policy component. The efficiency of the dialogue can be optimised using reinforcement learning [11], but this can result in an incoherent question policy. We aim to study policies that consider both efficiency and coherence.

Finally, the outcome of the dialogue should be explained. Such an explanation can be constructed based on the underlying argumentation setting, in various levels of detail. We plan to investigate the possibilities in a study answering research question Q5.

[2]https://aangifte.politie.nl/iaai-preintake/

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Towards Ordering Sets of Arguments

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1. Introduction

Formal argumentation [2] describes a family of approaches to modeling rational decision-making through the representation of arguments and their relationships. A particular important approach is that of abstract argumentation [4], which focuses on the representation of arguments and a conflict relation between arguments through modeling this setting as a directed graph. Here, arguments are identified by vertices and an *attack* from one argument to another is represented as a directed edge. This simple model already provides an interesting object of study, see [3] for an overview. Reasoning is usually performed in abstract argumentation by considering *sets of arguments*, i. e., sets of arguments that are jointly acceptable given some formal account of "acceptability". Therefore, this classical approach differentiates between "acceptable" arguments and "rejected" arguments.

In this paper, we take a more general perspective on this issue by considering orders—i. e., partial orders in the most general setting—over sets of arguments. So we want to compare different extensions based on their acceptability and then calculate an order accordingly to this comparison.

2. Motivation

The motivation behind our work is the need of a finer-grained assessment of the acceptability of arguments. The *ranking-based semantics* [1] is a line of work which provides an assessment of arguments more precisely it ranks arguments based on acceptability i. e. if argument a is at least as acceptable as argument b then $a \succeq^{\sigma} b$. There are a lot of different approaches like a ranking with respect to a categoriser function [6] or based on a two-person zero-sum strategic game [5].

However all these semantics only consider the relationships between arguments and do not look at the sets of arguments. So we propose a different type of semantics the *ordering semantics*, which provides a order over sets of arguments i. e. the set of arguments a, b is at least as acceptable as the set of arguments c, d then $\{a, b\} \succeq^{\sigma} \{c, d\}$.

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3. Research Question

The first step to order sets of arguments is to define a function, which can answer the question Is a set of arguments s_1 at least as acceptable as a set of arguments s_2?. The classical semantics already provide a simple way to answer this question: either the set satisfies the semantics or not. So we could define a function like: a set of arguments s_1 is at least as acceptable as a set of arguments s_2 if s_1 satisfies a semantics σ while s_2 does not satisfies the same semantic σ. However this function provides only two different levels i.e. s is satisfies semantics σ or not, and inside these levels we can not differentiate between two sets. So our aim should be to find a way to differentiate two sets on the same level, this is especially relevant when considering two sets of arguments that do not satisfy the classical semantics. With the classical semantics there is no way to differentiate these two sets. It is clear, that not every set of arguments which does not satisfy a specific semantics should be considered acceptable on the same level. Based on these observations we can determine two directions we should tackle in detail when we start from the classical semantics:

1. If a classical semantics gives multiple extensions for an argumentation framework, we can differentiate those with different levels of acceptability .
2. For two sets of arguments that are no extensions wrt. the classical semantics, we can differentiate those with different levels of acceptability.

While comparing sets it can occur, that two sets are not comparable and therefore we can not justify any kind of relationship between these sets. So we can not order every possible set easily we have to keep the incomparable sets in mind if we want to construct any ordering semantics.

One idea to define a ordering semantics is to look at the internal structure of the sets. For example we look at internal attacks so we want to consider a set like $s = \{a,b\}$, where a attacks b.

Example 1. Assume the three sets $s_1 = \{a,b\}$, $s_2 = \{c,d\}$ and $s_3 = \{e,f,g\}$, where c attacks d and e as well as f are attacking g. So s_2 has one internal attack and s_3 has two. If we consider a ordering semantic σ, which only counts the number of internal attacks, we get the following order: $\{a,b\} \succeq^{\sigma} \{c,d\} \succeq^{\sigma} \{e,f,g\}$. So this simple idea already present three different levels of acceptability.

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Epistemic Awareness Logics for Argumentation and its Dynamics

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Argumentative notions (such as argument, attack, counterargument or acceptability) and epistemic notions (such as belief, knowledge or justification) seem to be strongly intertwined in the daily life of epistemic agents. This connection happens in, at least, two different ways. On the one hand, (i) the evaluation that an agent performs of her available arguments is influenced by her epistemic attitudes. For instance, if an agent is looking for her best argument to persuade an opponent, she may choose the one that she believes to be more persuasive. On the other hand, (ii) a reasonable epistemic agent should take into account her available arguments in order to form some epistemic attitude (belief, knowledge and the like) towards a given proposition. Dynamics of information play a fundamental role in both kinds of scenarios. Regarding the first one, it directly includes a dynamic component, since the agent is reasoning about how her opponent will change her mind after communication has taken place. As for the second one, gaining availability of new arguments (trough reflection or communication) should make the agent accommodate her epistemic attitudes to them. The main objective of my PhD project is to study these relations through formal methods.

Clear methodological candidates for accomplishing such an objective are *formal argumentation*, understood in a broad sense [1], for modelling argumentative notions; and *dynamic epistemic logic* [2] for modelling epistemic attitudes and its dynamics. Although conceptually connected (as argued above), both lines of research have evolved mainly independently. The notion of awareness, as initially presented in [3], provides a natural bridge between both fields. In this regard, and taking up the kind of scenarios exposed in (i), believing that my opponent is aware of certain objections should prevent me from disclosing certain arguments. As for (ii), being aware of certain arguments may determine, e.g., whether I believe that it will rain in Brescia tomorrow. Note that the examples given to illustrate (i) had a clear rhetorical flavour. Although (i) can receive other readings, the first main line of the project focus on this idea.

Abstract persuasion and epistemic attitudes The relations between epistemic attitudes and persuasion can be analysed, at least partially, from an abstract perspective, by using Dung-style abstract argumentation frameworks (AFs) [4] as the basic construct. A preliminary problem arises here though, namely, given an abstract argumentation framework (A,R) [4], how can a finite set of agents Ag be brought into the picture? Although the different design options are vast, we can fairly say that there two main paths to follow: awareness of arguments and awareness of attacks.

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When focusing on awareness of arguments, the notion of multi-agent AF can be simply defined as $(\mathsf{A}, \mathsf{R}, \{\mathsf{A}_i\}_{i \in \mathsf{Ag}})$, where A_i represents the set of arguments that agent i is aware of. An important step in this direction was carried out by [5], where this version of multi-agent AFs were embedded in a Kripke model in order to capture each agent's uncertainty about what other agents are aware of. Following this idea, we proposed a sound and complete dynamic epistemic logic for awareness of arguments [6]. Using this logic, we can formally distinguish between what an agent believes to be persuasive (given her information about the arguments entertained by others) and what is actually persuasive. Moreover, we provided some conditions under which the beliefs of the agent are safe, in the sense that they guarantee her success. As an extension of [6], we are currently developing a full-fledged dynamic epistemic logic for abstract argumentation, integrating event models with factual change [7,8] in order to model more subtle aspects of persuasive communication.

According to the awareness-of-attacks perspective, which was first developed in [9], the set of all arguments, A, is assumed to be shared by all agents, and agent i's partial knowledge of the state of a debate is modelled through her awareness of the attack relation R_i. In another work which is currently under review, we have shown how second order knowledge about the attack relation is enough to characterize certain types of strategic communication. Both lines of work (awareness of arguments and awareness of attacks) have to face some challenges yet. For instance, increasing the expressive power of their languages in order to study more in detail the link between planning and persuasion, as spotted e.g. in the introduction of [10].

Justified belief and argument strength With respect to (ii), the idea of founding the epistemic attitudes of an agent in her available arguments is already present in the work of Dung [4] and more explicitly developed by frameworks of structured argumentation [11]. At the same time, researchers in epistemic logic have recently focused on including the missing justification component in their formal models of belief and knowledge. A customary attention has been paid here to justification logic [12], which, at least in some developments [13,14] can be easily compare to other approaches to structured argumentation. Other works [15,16,17] have opted for more semantic choices to model arguments and applied different argumentation semantics in order to obtain a logic of argument-based belief.

Our main contribution here consists in two ideas. First, observing that there is an epistemic reading of (i) that might be relevant for (ii), namely, that the beliefs of the agent with respect to the premises of her available arguments may crucially determine their relative strength. This idea was developed from a justification logic perspective in [18,19]. Second, in the present edition of COMMA [20], we have argued that there exists a conceptual tension between the epistemic reading of (i) and the notion of justified belief advocated in (ii). Moreover, we have proposed a formal solution to this tension, philosophically inspired in the foundationalist theories of epistemic justification [21]. This has been done by accommodating structured argumentation tools taken from ASPIC$^+$ [22] within awareness-epistemic models [3]. The resulting logic has a minimal, preliminary character though, since it only satisfies two of the four rationality postulates established in [23]. Therefore, an immediate line of work is studying whether certain restrictions on the awareness set of the formalize agent may make him more rational, i.e. by satisfying more postulates.

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