Argumentation for Knowledge Base Inconsistencies in Hybrid Intelligence Scenarios

Loan Ho[1], Victor de Boer[1], M. Birna van Riemsdijk[2], Stefan Schlobach[1] and Myrthe L. Tielman[3]

[1] *Vrije Universiteit Amsterdam, The Netherlands*
[2] *University of Twente, The Netherlands*
[3] *Interactive Intelligence Group, TU Delft, The Netherlands*

Abstract

Hybrid Intelligence (HI) is the combination of human and machine intelligence, expanding human intellect instead of replacing it. In HI scenarios, inconsistencies in knowledge bases (KBs) can occur for a variety of reasons. These include shifting preferences, user's motivation and or external conditions (for example, available resources and environment can vary over time). Argumentation is a potential method to address such inconsistencies as it provides a mechanism for reasoning with conflicting information, with natural explanations that are understandable to humans. In this paper, we investigate the capabilities of Argumentation in representing and reasoning about knowledge of both human and artificial agents in the presence of inconsistency. Moreover, we show how Argumentation enables Explainability for addressing problems in Decision-Making and Justification of an opinion. In order to investigate the applicability of Argumentation in HI scenarios, we demonstrate a mapping of two specific HI scenarios to Argumentation problems. We analyse to what extent of Argumentation is applicable by clarifying the practical inconsistency types of the HI scenarios that Argumentation can address. These include inconsistencies related to recommendations and decision making. We then model particularly the presentation of conflicting information for each scenario based on the form of argument representation.

Keywords

Hybrid Intelligence, Knowledge Representation and Reasoning, Argumentation, Explainability, Inconsistency, Preferences

1. Introduction

Artificial Intelligence (AI) systems are being applied in a variety of real-life situations. In recent years, AI applications are starting to go beyond machine reasoning by creating *Hybrid Intelligence (HI)* systems [1] to allow the combination of human and machine intelligence. Researchers have started to investigate how to integrate human and machines rather than using AI to replace human intelligence [2, 3]. In HI settings, artificial and human agents work together in complex environments. Such environments are rarely static. For example, preferences can shift, user's

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loanthuyho.cs@gmail.com (L. Ho); v.de.boer@vu.nl (V. de Boer); m.b.vanriemsdijk@utwente.nl (M. B. van Riemsdijk); k.s.schlobach@vu.nl (S. Schlobach); M.L.Tielman@tudelft.nl (M. L. Tielman)

[1] According to one definition, Hybrid Intelligence is "...the combination of human and machine intelligence, augmenting human intellect and capabilities instead of replacing them and achieving goals that were unreachable by either humans or machines" [1]. The work is a part of Hybrid Intelligence project.

motivation or external conditions (available resources and environment) can vary over time, etc. We outline various potential scenarios as motivating examples, which are mentioned in Section 3.1. These motivating examples illustrate the challenges in modeling knowledge of HI scenarios. In particular, knowledge of humans and artificial agents from such scenarios is likely to give rise to inconsistency due to heterogeneous data source integration and evolution, the change of preferences, and the change of the user's situation and wishes. Thus, the presence of inconsistency in many different HI scenarios has become a challenge for KRR.

Argumentation has become an essential paradigm for Knowledge Representation and, especially, for reasoning from contradictory information, for formalizing the exchange of arguments between agents in, e.g., negotiation and for commonsense reasoning, logic programming, legal reasoning and decision making. The advantages of Argumentation are that it suitably can represent anything from input data, e.g. categorical data and pixels in an image, to knowledge, e.g. rules, to problem formalisations, e.g. planning, scheduling or decision making models, to outputs, e.g. classifications, recommendations, or logical inference [4, 5]; it has strong explainability capabilities that allow users to understand the rationale of a decision, predictions or query answers through argumentation based explanations [6]. This flexibility and wide-ranging applicability has led to a multitude of methods for the application of argumentation in AI systems. However, it is notable that the existing works still have their limitations, i.e. they do not account for KRR in different HI scenarios.

To best our knowledge, modeling and reasoning in inconsistent knowledge bases w.r.t. HI systems is still a great challenge, especially in the context of human interaction, dynamic knowledge and preferences. Moreover, considering whether argumentation-based explanations make an HI system friendlier and more trustworthy to users has not been completely investigated [7]. We here address the following research challenges:

- **C1**. Where do inconsistencies exist in the knowledge of HI scenarios?
- **C2**. What are reasons for the inconsistency?
- **C3**. What are the capabilities of Argumentation in representing and reasoning knowledge of HI scenarios in the presence of inconsistencies?
- **C4**. How can Argumentation enable Explainability in HI scenarios?

In order to address the research challenges, this study provides an overview over the topics of Argumentation and KRR in HI scenarios in the presence of inconsistencies. For this purpose, we show for two specific and real-world HI scenarios how Argumentation can be used. For each project scenario, we clarify the practical inconsistency types of the HI scenarios that Argumentation solves, and model particularly the presentation of conflicting information for each scenario based on the form of argument representation. Then, we construct an argumentation tree as a dialectical dialogue to allow interaction between humans and agents.

The main contributions of this paper are as follows:

- We outline potential HI scenarios in two different application domain. These HI scenarios are real world HI scenarios from sub-projects of Hybrid Intelligence project (https://www.hybrid-intelligence-centre.nl/). Based on using qualitative data analysis methods, for each scenario, we show whether inconsistencies exist in the knowledge of HI scenarios and reasons leading to the inconsistencies. These contributions address **C1** and **C2**.

- We demonstrate the capabilities of Argumentation in representation and reasoning inconsistent knowledge base (KB) of HI scenarios. For this purpose, we study whether the representation of inconsistent KB maps into Argumentation Framework (AF) w.r.t the HI scenarios. This contribution addresses **C3**.
- We show how Argumentation can enable Explainability in the HI systems, for solving various types of problems in decision-making and justification of an opinion. The final contribution deals with **C4**.

2. State of the art in Argumentation

In this section, we present related works in term of Argumentation. Our intention is to provide an overview of related work in the field of Argumentation w.r.t. its capabilities and implementations in AI systems. Moreover, most existing works in this section focus on use-cases (scenarios) where knowledge of human and artificial agents is static. These works have not fully investigated modelling real general knowledge in which human and artificial agents work together in HI scenarios where complex environments of the HI scenarios are rarely static (e.g. conflicting information may result from shifting preferences, user aspects or changing over time). Our work aims to fill this gap, namely, we investigate to what extent these techniques can also be used for KRR in the context of HI scenarios.

Argumentation is becoming one of the main mechanisms for solving reasoning problems with conflicting information. Most of the research efforts in the area have focused on the development of reasoning technologies based on the original Dung's foundational work on *abstract argumentation theory* [8, 9, 10]. Calegari et al. [9, 10] sketch a vision of explainability of intelligent systems. In particular, they show how argumentation could be combined with different extensions of logic programming - namely, abduction, inductive logic programming, and probabilistic logic programming – to address the issues of explainable AI as well as some ethical concerns about AI. They then present *Arg2P*, a logic-based argumentation framework for defeasible reasoning and agent conversation, particularly suitable for explaining agent intelligent behaviours in the domain of computable law for autonomous vehicles. In some recent works, the authors place themselves in various argumentation frameworks to provide a useful platform for representing and reasoning with maximally consistent subsets of knowledge bases (KB) in propositional logic [11, 12, 13], in inconsistent ontological KBs [14, 15, 16] and in paraconsistent logics [17].

Another argumentation-based approaches recently have centered on formalizing *legal reasoning*, *commonsense reasoning*, *decision-making* and the exchange of arguments between agents in *negotiation*. Regarding *legal reasoning*, Prakken et al. provide a formalization of legal reasoning with cases into Argumentation Theory [18, 19, 20]. In the first two studies, the main idea is that the legal case is first given to the ASPIC framework that tries to produce defeasible rules, which are considered as arguments. Namely, the procedure of translating logical rules into arguments. The author proposes to represent legal cases as Dispute Trees and shows how an admissible argument is selected. In the later study, Sklar and Azhar [20] consider legal reasoning as an interchange between two or more agents based on Label-Based Argumentation Framework. The most crucial aspect of the work is the meta-level argumentation semantics. The authors introduce a set of logic rules with preferences that can be implemented in a Label-Based Argumentation Framework and change the procedure of how an admissible argument is derived. An approach to empower *commonsense reasoning* and make it more explainable with Argumentation is given in [21]. Botschen et al. investigate whether external knowledge of event-based frames and fact-based entities can contribute to decomposing an argument as stated in the Abstraction and Reasoning Corpus (ARC) task. In the ARC task, the system must find the correct cause that derives a claim given some data. It is similar to finding the warrant of an argument in Hunter's argumentation model [22]. Using *Argumentation-Based Dialogues* (ABD) to explain an opinion can be the most natural method of providing an explanation [23, 24]. The common idea of the studies is to analyse protocols to purchase negotiations using ADG. In the context where people or agents in a dialogue have an ostensible purpose, but their own goals or the goals of the other participants may not be consistent with this purpose. The negotiation protocols are proposed to allow the agents to perform negotiations in order to find the winning participant and to explain in more detail how the winner reached a decision.

Argumentation is highly related to *Decision-Making*. Indeed, the contributions of Argumentation can be support or opposition of a decision, reasoning for a decision, tackling KBs with inconsistency, and recommendations [25]. Several works with applications in recommendation systems (RSs) make use of Argumentation to support for explaining the result of decision-making. Several RSs have been built with DeLP as the main recommendation and explanation engine. One is that of [26] for the movie domain, handling incomplete and contradictory information and using a comparison criterion to solve conflicting situations. Another is introduced by [27], deploying DeLP to provide a hybrid RS in an educational setting, using argumentation to differentiate between different techniques for generating recommendations. Other approaches deploy other forms of AFs. For example, [28] provides argumentation-based review aggregations for movie recommendations and conversational explanations extracted from QBA frameworks, in turn, extracted from reviews by natural language processing.

3. Preliminaries

3.1. Hybrid Intelligence

We will first briefly introduce the concept of Hybrid Intelligence. According to one definition introduced in [1], "*Hybrid Intelligence is the combination of human and machine intelligence, expanding human intellect instead of replacing it. HI takes human expertise and intentionality into account when making meaningful decisions and perform appropriate actions, together with ethical, legal and societal values*". Then Hybrid Intelligent systems is a potential approach to Artificial Intelligence, which considers humans at the centre to change the course of the ongoing AI revolution. In the following example, we outline potential scenarios that illustrate the use of HI (namely, health care, assistants) in demonstrating its potential, and the challenges that the HI systems have been facing.

One example of a HI setting can be in *Digital Assistants*. In the example, an HI system can provide an application where agents can assist employees in calendar scheduling within a company. Assume that the employees do not know the calendars of other agents. The agents can change their calendar due to some reasons such as personal reasons, an urgent workplace matter,

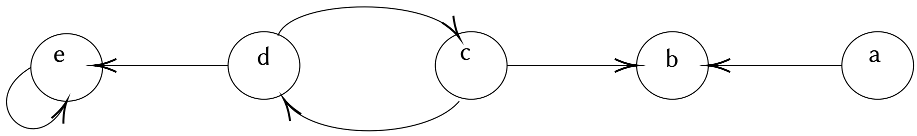

Figure 1: Argumentation framework for Example 1.

etc. Then, the employees might get conflicting proposals at the same time. Moreover, actions like rescheduling or denying meetings must be explained to the user. Providing explanation functionalities is indeed necessary to allow the user to understand the rationale of a decision or prediction, so as to choose whether trust them or disregard them.

3.2. Argumentation

We briefly recall the notion of *Abstract Argumentation Framework* (AF) and related definitions, which are originally introduced by Dung [8].

Abstract Argumentation Framework. An abstract argumentation is a pair $\mathscr{A} = (Arg, Att)$ where Arg is the set of arguments, and $Att \subseteq Arg \times Arg$ is the *attacking relation* i.e., $(A, B) \in Att$ means *A attacks B*.

Extensions. Semantics of AAF are specific subsets of arguments, which are defined from the aforementioned properties. Let $\mathscr{A} = (Arg, Att)$ be an AAF and $\mathscr{M} \subseteq Arg$. We say that: (1)$\mathscr{M}$ is an *admissible extension* if $\mathscr{M}$ is conflict-free and defends each argument in it. (2) $\mathscr{M}$ is a *complete extension* (*cmp*) if $\mathscr{M}$ is an admissible extension containing all arguments that it defends. (3) $\mathscr{M}$ is a *preferred extension* (*prf*) if $\mathscr{M}$ is a maximal (w.r.t. set inclusion) admissible extension. (4) $\mathscr{M}$ is a *stable extension* (*stb*) if $\mathscr{M}$ is a conflict-free and attacks every argument which is not in it. (5) $\mathscr{M}$ is a *grounded extension* (*grd*) if $\mathscr{M}$ is a minimal (w.r.t. set inclusion) complete extension. We refer to an extension under a semantics $S \in \{stb, prf, cmp, grd\}$ also as S-extension.

Acceptance. In order to evaluate the arguments, two types of acceptance are introduced in terms of their extensions: the *sceptical* and *credulous* acceptance. We say that an argument A is *sceptically* (*credulously*) accepted w.r.t. a semantic S iff it is in all extensions (at least one extension) under S.

Example 1. *Let us consider an AF* $\mathscr{A} = (Arg, Att)$ *where* $Arg = \{a, b, c, d, e\}$ *and* $Att = \{(e,e), (d,e), (d,c), (c,d), (c,b), (a,b)\}$*, illustrated in Figure 1. We can make the following observations: The admissible extensions are* $\{a\}, \{c\}, \{d\}, \{a,d\}, \{a,c\}$ *and* $\emptyset$*. The complete extensions are* $\{a\}, \{a,c\}, \{a,d\}$ *and* $\emptyset$*. The preferred extensions are* $\{a,c\}$ *and* $\{a,d\}$*. The stable extension is* $\{a,d\}$*. The grounded extension is* $\{a\}$*.*

In abstract argumentation, any information which may be in dialectical relationships of disagreement (attack) with other information may be considered to be an argument, and arguments (according to this loose interpretation of the term) typically have a negative or positive impact on the acceptability of arguments they attack. In this spirit, we recall the notion of the argumentation tree introduced in [29]. An *argumentation tree* called a dispute tree is a description of how these arguments are defended or attacked. Based on argumentation trees, a dialogical process of explanation is described as follows:

Dialogical explanation. A dialogical process of explanation is a two-person argument game between a proponent and an opponent. The proponent and the opponent are engaged in an argumentation dialogue of a sequence of moves. The dialogue starts by the proponent with an initial argument. Then, the opponent presents an argument (or a set of arguments) that attacks the initial argument of the proponent. Next, the proponent tries to avoid this attack and reinstate the query by using another argument which is not attacked by the opponent. The opponent tries to extend the previous set of attackers so that it attacks all the initial arguments advanced so far. When the opponent fails to extend the set, it retraces back and chooses another set of attackers and continues the dialogue from thereafter. By doing so, the opponent is trying to construct a set of arguments that attacks all the initial argument.

We recall the notion of *Structured Argumentation Framework (SAF)* as an extension of Abstract Argumentation Framework, which is proposed [14]. SAF represents the arguments in the form of logical rules and the attack relations capture the contrary information between the arguments. First, we need to define some concepts. A KB $\mathscr{K} = \{\mathscr{R}, \mathscr{C}, \mathscr{F}\}$ where $\mathscr{F}$ is a set of facts, $\mathscr{C}$ is set of negative constraints, and $\mathscr{R}$ is a set of rules which follow the general form: $R : a \leftarrow b_1, \ldots, b_n$ (claim $\leftarrow$ premise). Then, we recall the definition of SAF.

Structured Argumentation Framework. Let $\mathscr{K} = (\mathscr{F}, \mathscr{R}, \mathscr{C})$ be a KB. The corresponding SAF is the pair (Arg', Att') such that an argument $A \in Arg'$ is a tuple (H, C) with H a non-empty $\mathscr{R}$-consistent subset of $\mathscr{F}$ and C a set of facts s.t. (1) $C \subseteq SAT(H)$ and (2) there is no $H_0 \subset H$ s.t. $C \subseteq SAT(H_0)$. The support H of an argument A is denoted by $Supp(A)$ and the conclusion C by $Conc(A)$. A attacks B, denoted by $(A, B) \in Att'$ iff there exists $\alpha \in Supp(B)$ s.t. $Conc(A) \bigcup \{\alpha\}$ is $\mathscr{R}$-inconsistent, where $SAT(H)$ is called the saturation of a set of facts H. [2]

4. Mapping HI scenarios to AF

In this section, we show how the capabilities of argumentation can support representing and reasoning conflicting knowledge bases in HI use-cases (scenarios). Our goals are to show (1) the capabilities of Argumentation in representation and reasoning inconsistent KBs, and (2) how Argumentation enables Explainability in these use-cases (scenarios). For this purpose, we describe in this paper two distinct HI scenarios. Both these scenarios are addressed in the Hybrid Intelligence project (https://www.hybrid-intelligence-centre.nl/) and as such can be considered real-world scenarios. For each use-case (scenario), we conduct the following steps:

- We explore whether inconsistencies can occur in the scenarios and the reasons why the inconsistencies can occur. This step addresses the challenges **C1** and **C2**.
- We study the use of argumentation by showing how argumentation represents conflicting information and what they explain when solving these problems in Decision-making and Justification. In particular, in the argumentation setting, we show that arguments represent

[2] According to [30], the saturation of a set of facts $\mathscr{F}$ by $\mathscr{R}$ is the set of all possible atoms and conjunctions of atoms that are entailed, after using all rule applications from $\mathscr{R}$ over $\mathscr{F}$ until a fixed point.

facts of KB and attack relations between the arguments capture conflicting information. Then, we construct an argumentation tree as a dispute tree. Based on the argumentation tree, we provide a dialectical dialogue of explanation to allow interaction with humans. Then, we describe how Argumentation enables Explainability according to what they explain (i.e. providing explanations through Decision-Making and Justification). This step deals with the challenges **C3** and **C4**.

Next, we will introduce the mapping of two use-cases (scenarios) (i.e., *Digital Assistant* and *Biographical data*) to the AF, which is the main result of this paper.

4.1. Scenario 1: Digital Assistant - Decision-making with argumentation

Argumentation is highly related to Decision-Making. In fact, it has been stated that Argumentation was proposed in order to facilitate Decision-Making [25]. The contributions of Argumentation are support or opposition of a decision, reasoning for a decision, tackling KBs with inconsistency, and recommendations. In order to illustrate the contributions of Argumentation for supporting Decision-Making problem, we consider the following scenario of *Project 9 - AutoAI for dynamic data*, in which Project 9 is a sub-project of HI project (https://www.hybrid-intelligence-centre.nl/).

Argumentation is used to explain a *decision-making* for calendar scheduling of the agents in a **Digital Assistant** application. Particularly, *Project 9* constructs a system to assist employees in calendar scheduling within a company. The system has multiple agents that are independently operating, and each agent is assigned a task to setup a meeting and manage their calendar. The agents work independently and attempt to set meetings through bargaining games. The environment in the system is rarely static: Agents are added and removed, other agents can change their calendar, agents have preference over the offer of the user that they are making and the preference can change over time. Conflicting information among agents may result from dynamic environment. For example, other agents can change their calendar, the system might get conflicting proposals over time. In such system, actions like rescheduling or denying meeting must be explained to the user. Mapping the use-case to the AF is illustrated as follows: *Imagine we have the options (1) book this meeting at 10am, (2) do not book this meeting at 10am. The agent schedules the meeting at 10am. Then, we have an argument for booking this meeting at 10am. Unfortunately, the manager got sick, and he will not be able to join the meeting. He postpones the meeting. Then, we have a new argument not to book the meeting at 10am*. In the case, the system should explain to staffs why the meeting is postponed. We use temporal datalog, which is introduced in [31], to model the scenario as follows: Consider $\mathscr{K}_2 = \{\mathscr{R}_2, \mathscr{C}_2, \mathscr{F}_2\}$, in which: $\mathscr{R}_2 = \{R_1 : manager(x) \rightarrow bookMeeting(x,y,t_1), R_2 : manager(x) \wedge gotSick(x,sick) \rightarrow cancelMeeting(x,y,t_2)\}$, $\mathscr{C}_2 = \{C : \forall \text{x,y } bookMeeting(x,y,t_1) \wedge cancelMeeting(x,y,t_2) \wedge (t_1 = t_2) \rightarrow \perp\}$, $\mathscr{F}_2 = \{f_1 : manager(Tim), f_2 : bookMeeting(Tim, meetingA, 10am),$
$f_3 : gotSick(Tim, sick), f_4 : cancelMeeting(Tim, meetingA, 10am)\}$. In the KB, rule R_1 states a meeting is booked by a manager at a certain time t_1. Rule R_2 represents that if a manager got sick, the meeting is not booked by the manager at a certain time t_2. We use Rule C to express the contrary information when booking a meeting. Facts f_1, f_2, f_3, f_4 represent instances of the KB.

After translating of the KB into Argumentation framework, an attack relation between two arguments A_1 and A_2 is used to model contrary information when booking the meeting, where:

$A_1 = (\{manager(Tim)\}, \{bookMeeting(Tim, meetingA, 10am)\})$,
$A_2 = (\{manager(Tim), gotsick(Tim, sick)\}, \{cancelMeeting(Tim, meetingA, 10am)\})$. Two conflicting arguments represent: A_1 states that the meeting A is booked by the manager Tim at 10am, A_2 states that the manager Tim got sick and the meeting A is not booked by him. And now we construct an argumentation tree as follows.

$$\begin{array}{c} A_1 = (\{manager(Tim)\}, \{bookMeeting(Tim, meetingA, 10am)\}) \\ \Big\uparrow \; C : bookMeeting(x,y,t_1) \wedge cancelMeeting(x,y,t_2) \wedge (t_1 = t_2) \rightarrow \bot \\ A_2 = (\{manager(Tim), gotsick(Tim, sick)\}, \{cancelMeeting(Tim, meetingA, 10am)\}) \end{array}$$

Based on the argumentation tree, a dialogical process between the assistant agent and the user is as follows.

User: Why not $bookMeeting(Tim, meetingA, 10am)$ given that A_1? [3]	
	Reasoner: Because $cancelMeeting(Tim, meetingA, 10am)$ [4] the following constraint is violated: C : $\forall$x,y $bookMeeting(x,y,t) \wedge cancelMeeting(x,y,t) \rightarrow \bot$
User: I understood the reason "why the meeting A is not booked at 10am"!	

4.2. Scenario 2: Biographical data - Justification through argumentation

Justification is a form of explaining an argument, in order to make it more convincing and persuade the opposing participant(s). Justification means that, where with the help of Argumentation and Dispute Trees, we can show how easy it is to justify if an argument is acceptable or not. To demonstrate the Explainability of Argumentation for supporting Justification of an opinion, we analyse the following scenario (The scenario is one of case studies in *Project 26 - Knowledge Representation Formalisms for Hybrid Intelligence*, which is a sub-project of HI project (https://www.hybrid-intelligence-centre.nl/).

Query-Answer (QA) system is another application in HI projects. The application is a part of our work in *Project 26*. The work investigates a reasoning technique in inconsistent KB for Biographical domain, in which Biographical domain is integrated data from heterogeneous sources can be diverse and change over time [32], to allow interaction with users. A simple example is: *A person has birthdays provided from different data sources and his birthdays are different. This leads to inconsistent information about the person's birthday*. Querying in inconsistent knowledge is non-trivial . Additionally, in such QA system, the users need to

[3] $A_1 = (\{manager(Tim)\}, \{bookMeeting(Tim, meetingA, 10am)$

[4] $A_2 = (\{manager(Tim), gotsick(Tim, sick)\}, \{cancelMeeting(Tim, meetingA, 10am)\})$ is a counter-argument of A_1.

understand why the answer is accepted for the query and which information of the person's event conflicts with others. Thus, proving explanation functionalities that enable the users to understand the rationale of an answer is indeed necessary. In our project, we take into account argumentation theory to support the inconsistent-tolerant query answering in inconsistent KBs. We start with a very simple scenario: *An user queries "When did Thorbecke die?" that expressed as* $Q(x) = Person(Thorbecke) \wedge hasDeathdate(x)$. *The QA system returns an answer "*14^{th} *Oct 1860" for the query. The user expected that "*10^{th} *Oct 1860" is also an answer. The user want to understand why "*10^{th} *Oct 1860" is not the answer of his query.*

In what follows, we use Datalog $^{\pm}$, which is introduced in [30], to represent a KB of this project as follows: Consider $\mathscr{K}_1 = \{\mathscr{R}_1, \mathscr{C}_1, \mathscr{F}_1\}$ where: $\mathscr{R}_1 = \{R : \forall x Person(x) \rightarrow \exists y hasDeathdate(x,y)\}$, $\mathscr{C}_1 = \{C : \forall \text{x,y,z } Person(x) \wedge hasDeathdate(x,y) \wedge hasDeathdate(x,z) \rightarrow y = z\}$, $\mathscr{F}_1 = \{f_1 : Person(Thorbecke), f_2 : hasDeathdate(Thorbecke, 14/10/1860)$, $f_3 : hasDeathdate(Thorbecke, 10/10/1860)\}$. In the KB, rule R models the concept of a person who has a death date. Rule C represents fundamental constraints: If a person has two death dates, the death dates coincide. Facts f_1, f_2, f_3 express that Thorbecke has death dates that are 14/10/1860 and 10/10/1860 respectively.

We now translate the KB $\mathscr{K}$ into Argumentation framework. In such argumentation setting, we have a set of arguments: $A_1 = (\{Person(Thorbecke)\}, \{hasDeathdate(Thorbecke, 14/10/1860)\})$, $A_2 = (\{Person(Thorbecke)\}, \{hasDeathdate(Thorbecke, 10/10/1860)\})$ and A_1 attacks A_2 since $hasDeathdate(Thorbecke, 14/10/1860)$ is in conflict with $hasDeathdate(Thorbecke, 10/10/1860)$. A_1 models a death date 14/10/1860 of Thorbecke and A_2 states that Thorbecke has a death date that is 10/10/1860. Then we construct an argumentation tree as follows.

$$
\begin{array}{l}
A_2 = (\{Person(Thorbecke)\}, \{hasDeathdate(Thorbecke, 10/10/1860)\}) \\
\qquad\qquad\qquad\qquad \Big\uparrow \; C : Person(x) \wedge hasDeathdate(x,y) \wedge hasDeathdate(x,z) \rightarrow y = z \\
A_1 = (\{Person(Thorbecke)\}, \{hasDeathdate(Thorbecke, 14/10/1860)\})
\end{array}
$$

Based on the argumentation tree, a dialogical process that explains to the user is the following:

User: Why not $hasDeathdate(Thorbecke, 10/10/1860)$ given that A_2? [5]	
	Reasoner: Because $hasDeathdate(Thorbecke, 10/10/1860)$ [6] the following constraint is violated: $\forall$x,y,z $Person(x) \wedge hasDeathdate(x,y) \wedge hasDeathdate(x,z) \rightarrow y = z$,
User: I understood the reason "why 10/10/1860 is not Thorbecke's death date"!	

[5] $A_2 = (\{Person(Thorbecke)\}, \{hasDeathdate(Thorbecke, 10/10/1860)\}$ is an argumentation where $Q =$

The above example shows the need for explanation facilities to help the user to understand why an answer of the query holds and fails. Through this example, we show how the capabilities of the AF allow interaction with human in the QA system.

5. Conclusion

In this paper, we elaborated over the topic of Argumentation in Hybrid Intelligence project. Our goals were to (1) demonstrate the capabilities of Argumentation in representing and reasoning about knowledge of both human and artificial agents in the presence of inconsistency in HI, (2) show how Argumentation enables Explainability in these use-cases (scenarios). For these purposes, we considered two specific and real-world HI scenarios. For each scenario, we analyse to what extent of Argumentation is applicable by clarifying the practical inconsistency types of the HI scenarios that Argumentation can address. We then model particularly the presentation of conflicting information for each scenario based on the form of argument representation. Based on the mapping of the HI scenarios to Argumentation, this work shed light on the capabilities of Argumentation in providing a mechanisms for reasoning and providing explanations that are understandable to humans. The main results of the paper were showed in Section 4.

As future work, we plan to analyse all scenarios of sub-projects, and extend our work for modeling and implementation for the scenarios of all sub-projects. Moreover, our future work may materialize human–machine dialogue from human text dialogues in the HI scenarios, which has not yet received much attention. Causality [7] could be achieved by reasoning over each step that led to a decision and explain why alternatives were left out. Nevertheless, we see that not many works exist that combine Argumentation and causality for this purpose. Therefore, we plan to focus on arguments with commonsense knowledge, an interesting area that has not yet received much attention.

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References

[1] Z. Akata, D. Balliet, M. de Rijke, F. Dignum, V. Dignum, G. Eiben, A. Fokkens, D. Grossi, K. Hindriks, H. Hoos, H. Hung, C. Jonker, C. Monz, M. Neerincx, F. Oliehoek, H. Prakken, S. Schlobach, L. van der Gaag, F. van Harmelen, H. van Hoof, B. van Riemsdijk, A. van Wynsberghe, R. Verbrugge, B. Verheij, P. Vossen, M. Welling, A research agenda for hybrid

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$hasDeathdate(Thorbecke, 10/10/1860)$ is a conclusion of A_2

[6] $A_1 = (\{Person(Thorbecke)\}, \{hasDeathdate(Thorbecke, 14/10/1860)\})$ is a counter-argument of A_2

[7] Collins et al. have presented types of *causality* in their paper "Towards an argumentation-based approach to explainable planning" (https://nms.kcl.ac.uk/simon.parsons/publications/conferences/xaip19.pdf)

intelligence: Augmenting human intellect with collaborative, adaptive, responsible, and explainable artificial intelligence, Computer 53 (2020) 18–28.

[2] S. Sankar, The rise of human-computer cooperation (2021). URL: https://www.ted.com/talks/shyam_sankar_the_rise_of_human_computer_cooperation/transcript?language=en.

[3] L. Chen, H. Ning, C. D. Nugent, Z. Yu, Hybrid human-artificial intelligence, Computer 53 (2020) 14–17.

[4] A. Vassiliades, N. Bassiliades, T. Patkos, Argumentation and explainable artificial intelligence: a survey 36 (2021) e5.

[5] T. Miller, Explanation in artificial intelligence: Insights from the social sciences, Artificial Intelligence 267 (2019) 1–38.

[6] K. Cyras, A. Rago, E. Albini, P. Baroni, F. Toni, Argumentative XAI: A survey, CoRR abs/2105.11266 (2021).

[7] C. Roberta, C. Giuseppe, L. Francesca, O. Andrea, S. Giovanni, Defeasible systems in legal reasoning: A comparative assessment, Frontiers in Artificial Intelligence and Applications (2019) 169 – 174.

[8] P. M. Dung, On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games, Artif. Intell. 77 (1995).

[9] R. Calegari, A. Omicini, G. Sartor, Explainable and ethical ai: A perspective on argumentation and logic programming, in: M. Baldoni, S. Bandini (Eds.), AIxIA 2020 – Advances in Artificial Intelligence, 2021.

[10] R. Calegari, A. Omicini, G. Pisano, G. Sartor, Arg2P: an argumentation framework for explainable intelligent systems, Journal of Logic and Computation (2022) 369–401.

[11] O. Arieli, A. Borg, C. Straundefineder, Prioritized sequent-based argumentation, in: Proceedings of the 17th International Conference on Autonomous Agents and MultiAgent Systems, International Foundation for Autonomous Agents and Multiagent Systems, Richland, SC, 2018, p. 1105–1113.

[12] M. D'Agostino, S. Modgil, A study of argumentative characterisations of preferred subtheories, in: Proceedings of the Twenty-Seventh International Joint Conference on Artificial Intelligence, IJCAI-18, International Joint Conferences on Artificial Intelligence Organization, 2018, pp. 1788–1794.

[13] J. Heyninck, C. Straundefineder, A fully rational argumentation system for preordered defeasible rules, in: Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems, AAMAS '19, 2019, p. 1704–1712.

[14] A. Arioua, M. Croitoru, S. Vesic, Logic-based argumentation with existential rules, International Journal of Approximate Reasoning 90 (2017) 76 – 106.

[15] B. Yun, S. Vesic, M. Croitoru, Sets of Attacking Arguments for Inconsistent Datalog Knowledge Bases, in: COMMA 2020 - 8th International Conference on Computational Models of Argument, volume 326 of *Frontiers in Artificial Intelligence and Applications*, ????, pp. 419–430.

[16] M. Bienvenu, C. Bourgaux, Querying and repairing inconsistent prioritized knowledge bases: Complexity analysis and links with abstract argumentation, CoRR abs/2003.05746 (2020).

[17] J. BenNaim, Argumentation-based paraconsistent logics, in: N. Hernandez, R. Jäschke, M. Croitoru (Eds.), Graph-Based Representation and Reasoning, Springer International

Publishing, Cham, 2014, pp. 19–24.
[18] H. Prakken, Logics of Argumentation and the Law, 2017, p. 3–31.
[19] H. Prakken, A. Wyner, T. Bench-Capon, K. Atkinson, A formalisation of argumentation schemes for legal case-based reasoning in aspic+, Journal of Logic and Computation (????) 1141–1166.
[20] E. Sklar, M. Q. Azhar, Argumentation-based dialogue games for shared control in human-robot systems, in: HRI 2015, 2015.
[21] T. Botschen, D. Sorokin, I. Gurevych, Frame- and entity-based knowledge for common-sense argumentative reasoning, in: Proceedings of the 5th Workshop on Argument Mining, 2018.
[22] P. Besnard, A. Hunter, Argumentation Based on Classical Logic, 2009, pp. 133–152.
[23] L. Amgoud, N. Maudet, S. Parsons, Modelling dialogues using argumentation, in: Proceedings Fourth International Conference on MultiAgent Systems, 2000, pp. 31–38.
[24] P. Pilotti, A. Casali, C. Chesñevar, A belief revision approach for argumentation–based negotiation agents, International Journal of Applied Mathematics and Computer Science 25 (2015).
[25] H. Mercier, D. Sperber, Why do humans reason? arguments for an argumentative theory, Behavioral and Brain Sciences 34 (2011) 57–74. doi:10.1017/S0140525X10000968.
[26] C. E. Briguez, M. C. Budan, C. A. D. Deagustini, A. G. Maguitman, M. Capobianco, G. R. Simari, Argument-based mixed recommenders and their application to movie suggestion, Expert Syst. Appl. 41 (2014) 6467–6482.
[27] P. Rodríguez, S. H. Barberá, J. Palanca, J. M. Poveda, N. D. Duque, V. Julián, An educational recommender system based on argumentation theory, AI Commun. 30 (2017) 19–36.
[28] O. Cocarascu, A. Rago, F. Toni, Extracting dialogical explanations for review aggregations with argumentative dialogical agents, in: Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems, AAMAS '19, International Foundation for Autonomous Agents and Multiagent Systems, Richland, SC, 2019, p. 1261–1269.
[29] P. Besnard, A. Hunter, A logic-based theory of deductive arguments, Artificial Intelligence 128 (2001) 203–235.
[30] A. Cali, G. Gottlob, T. Lukasiewicz, A. Pieris, Datalog+/-: A family of languages for ontology querying, volume 6702, 2011, pp. 351–368.
[31] A. Ronca, M. Kaminski, B. C. Grau, B. Motik, I. Horrocks, Stream reasoning in temporal datalog, AAAI'18/IAAI'18/EAAI'18, AAAI Press, 2018.
[32] C. Dijkshoorn, L. Aroyo, J. V. Ossenbruggen, G. Schreiber, Modeling cultural heritage data for online publication, Appl. Ontology 13 (2018) 255–271.