OntoImpact*: The Fundamentals of a Collaborative Impact Projection of Complex Decision

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Abstract

Complex decisions can be understood as an unpredictable process, uncommon and composed of actions. To handle this complexity, it is necessary to think and apply strategies to mitigate the risks and the unpredictable actions concerned to a decision making. Design the complex decision impact can bring alternatives to solve problems with less damage to the environment and humans involved. In this paper, we propose an impact projection's conceptualization, modelled into an ontology called OntoImpact*. This ontology proposal has a differential in representing the state of art about complex decisions impact, through the decision-making process, impact characterizers, agents involved and contextual information. This ontology is based on the unified foundational ontology (UFO) and is organized into five aspects: decision agents and domain characteristics; collaboration aspects; complex decision process and activities; structural elements of impact projection; and impact details. In this paper we present the contribution of UFO in the meaning of OntoImpact*.

Keywords

Complex decision, UFO, Impact Projection, Collaborative Environment

1. Introduction

Decision-making is a common process in humans' life. The more diverse the environment in which the decision is made, the complex are the tasks. Every day, decision makers face decision tasks that are chaotic, complex, and interrelated [20, 30]. A complex decision can be understood as a complex system, composed of interrelated variables [10, 9]. It is difficult to isolate the elements that influence such a decision. Their impacts are interdependent, and the environment in which they are embedded generates constant change [6]. Decisions are made by individuals, and are affected by the environment and by perceptions, beliefs and experiences. Traditionally, decision-making process was viewed as a rational behavior; however, human decisions and tasks are influenced by intuition, perception, creativity, and emotional responses to a much greater extent than previously thought [3, 30, 4]. Based on these aspects, this research understands complex decision as the one that encompasses the principles of the Naturalistic Decision Making (NDM) [27, 25].

Impact projection is a natural initiative in decision making field. However, it is a tacit or individual task. Some research [19, 21-24, 33] have argued the importance of projecting the impact of complex decisions in a shared way; however, their models do not explicitly offer a way of conducting collaborative impact analysis, considering not only the explicit knowledge and data bases, but the tacit knowledge developed by decision-makers based on previous experiences and cognitive attributes such as intentions, beliefs or desires [4].

This research extends our previous work [4] in which a preliminary version of impact projection conceptualization was developed and evaluated by decision maker specialists. The results showed a need for more expressiveness in the conceptual model. The present work extends the conceptualization,

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focus on the unified foundational ontology (UFO), a top-level ontology based on philosophic and cognitive theories [12-14].

The main contribution of this paper is the OntoImpact*. It is an ontology, with new theoretical discussions on its semantic expressiveness. This ontology comprises concepts from several perspectives related to decision impact, and it is organized in five modules: decision agents and domain characteristics; collaboration; process and activities; the structural elements; and impact details.

In practice, OntoImpact* is intended to form the basis to analyze a set of complex decisions from the perspective of their impacts, in a deep way. This ontology plays the role to externalize the concepts and its relations, able to influence decision analysts on their analysis, especially the decisions classified as naturalistic decision making (NDM). In this paper, we present the ontology`s development process, highlighting the concepts, its origins, relationships, and the semantic improved by UFO.

The paper is organized as follows: Section 2 presents fundamental concepts regarding the impact projection of complex decisions and related work; Section 3 presents OntoImpact*; Section 4 analyses OntoImpact*; and Section 5 concludes the paper and highlights future directions.

2. Relation Between Impact Projection and Complex Decision-Making

An impact is a measure of the tangible and intangible consequences. Project impacts involves making predictions of potential future outcomes [28]. It is possible to find works in the literature that discuss the impact of a decision in the planning phase of the decision process [19] and Table 1 shows examples. However, most research in this area does not provide the details of how to effectively project an impact in practice, and especially the impacts of complex decisions. Most prior research deals with subjectively designed impacts that are intrinsic to the decision maker's experience and their mental correlations [34]. According to [6], the mental representations that are involved in dynamic systems and exercised are inadequate. The so-called mental models, intended to attempt to mentally replicate the relationships structure of a complex system, play an important role in the decision-maker's orientation. However, it is difficult to ensure whether the externalized verbally or diagrammatically mental model corresponds exactly to the existent mental model in the individual human mind.

The decision support and impact projection approaches found in the literature include smart choice [19] situation assessment [26], RPD and its variations [21], the dynamic model of situational cognition [33], decision making using stairs [32, 35], decision trees [2], decision ontology [29] and extended IBIS [1, 20] (Table 1). They are classified as normative or descriptive approaches (like RPD [27]), however, for this paper discussion, all of them can express ideas and/or follow-steps to support complex decision making. Some of them discuss the complete cycle of decision management and most of them treat, in some way, the impacts of complex decisions on other decisions or in the environment.

Table 1:
Approaches to support complex decisions analysis - Literature revision consolidated

Approaches	Decision Management				Impact	Human Aspect	Group	Technology
	Plan	Do	Act	Check				
Smart choice	✓	✓	✓	✓	✓	✓	✓	
Situation assessment	✓	✓	✓	✓		✓	✓	✓
RPD and its variations	✓	✓	✓	✓	✓	✓	✓	
The dynamic model of situational cognition	✓	✓			✓	✓	✓	✓
Decision making using stairs	✓	✓			✓	✓	✓	
Decision trees	✓				✓	✓	✓	
Decision ontology	✓				✓	✓	✓	
Extended IBIS	✓				✓	✓	✓	✓

Decision impacts are considered in different ways in seven of eight approaches verified. The decision-making approaches in Table 1 support impact discussion. Despite this, little work has been done on systematizing the impacts projection of complex decisions still in the planning phase of the

decision process, considering the cognitive aspects of the decision-makers involved and facing lack or ambiguous information about the decision.

In view of these considerations, we propose a formal conceptualization for the impact projection of complex decisions, based on the characterization elements mentioned above and on the existing understanding of impact projection. This conceptualization is represented in the form of OntoImpact*, an ontology based on UFO [12], which is presented below. This ontology is a way to consolidate aspects of scientific, engineering, and humanistic (that are the elements that support a problem-solving), representing the elements involved on the impact project of complex decisions. Mainly, OntoImpact* aims to provide a conceptual structure to support decision makers on the applicability of their cognitive elements on the complex decision understanding and impact projection.

3. OntoImpact*: An Impact Projection Ontology Based on UFO

An ontology represents an abstraction of reality and explicit a shared conceptualization [11]. This paper presents and discusses OntoImpact* that is an extension of OntoImpact [4]. OntoImpact* is an ontology developed based on naturalistic decision making (NDM) fundamentals. Its structure followed the SABiO method [7], and the competence questions applied to discover the OntoImpact concepts were well discussed in [4]. OntoImpact* is a conceptual structural related to complex decision impact projection, able to optimize decision results, identify interdependencies and conflicts, organize impact actions, identify potential decision execution problems, and specify markers for monitoring the progress of decisions impacts.

OntoImpact* involves the search for existing ontologies related to domain and scope that were established in the previous steps of development of this ontology. Two proposals of interest for reuse were found in the development of OntoImpact*: the knowledge-intensive process ontology (KIPO) [5] and OntoEmerge, a supporting ontology for an emergency plan [8]. The decision to reuse these proposals was based on a semantic evaluation of the constructs of these ontologies in relation to the attributes characterizing the complex decision and projection of impacts [4]. The notation used to present OntoImpact* is the same applied in KIPO [5], based on UML class diagrams. To support the definition of the structure of OntoImpact*, we analyzed the concepts involved and organized them into five groups.

3.1. Decision agents and domain characteristics (AC)

The cognitive aspects and competencies of decision makers related to impact projection can be seen in Figure 1. The impact projection for a complex decision involves several agents that may be specialists or decision makers, with specific backgrounds and rationales.

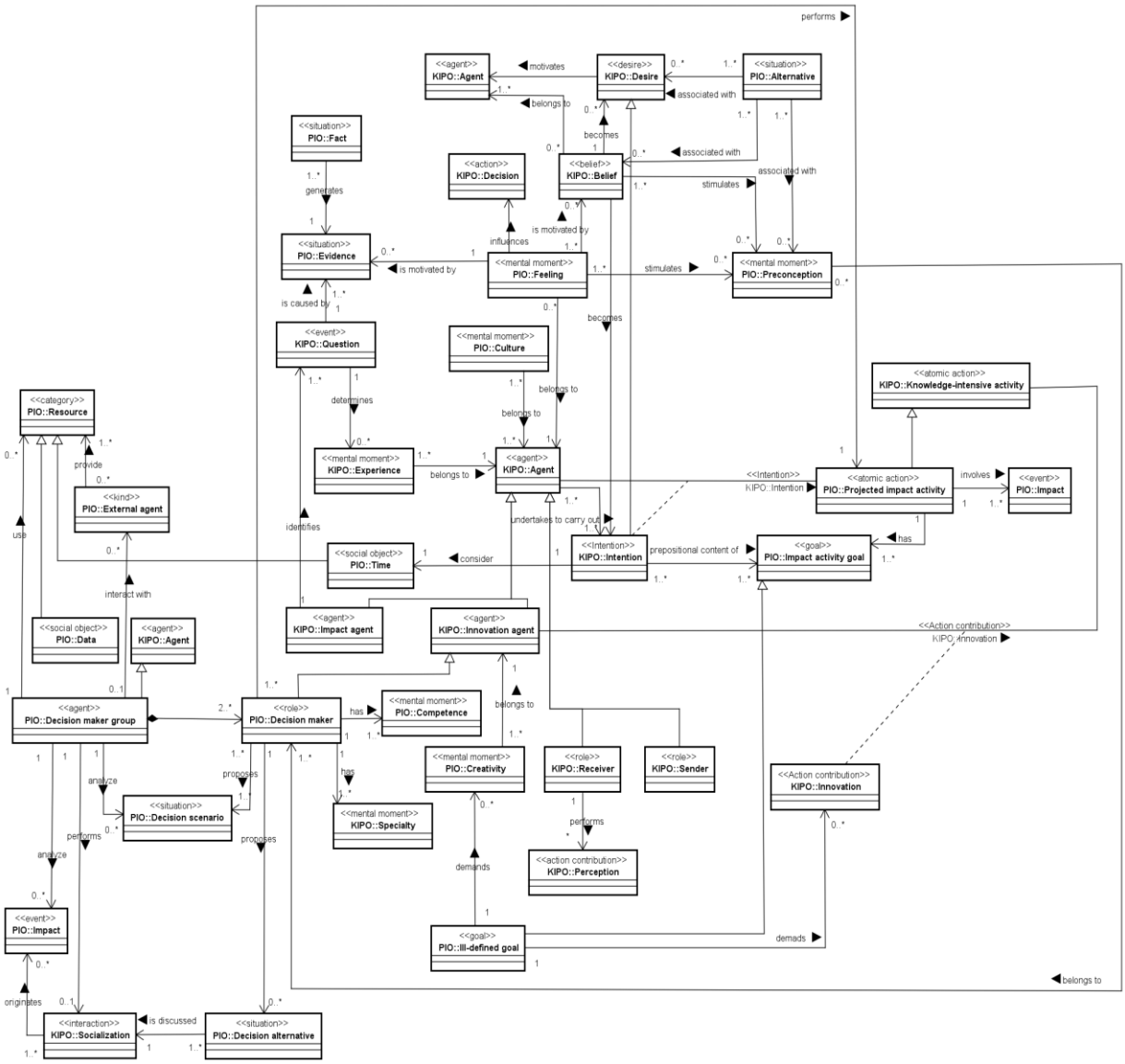

Figure 1: The AC Module.

3.2. Collaboration to Support Impact Projection (Collab)

Collaboration is an important aspect to improve exchange and development of knowledge. In impact projection of complex decision, it is a determining factor in the analysis, discovery, and implementation of new tasks. In the domain modelled by OntoImpact*, socialization is a central interaction that permits discussion and analysis of the main concepts, such as decision alternatives, the decision scenario, and impacts. Figure 2 presents the Collab, providing a shared understanding of how collaboration can improve impact projection of complex decisions.

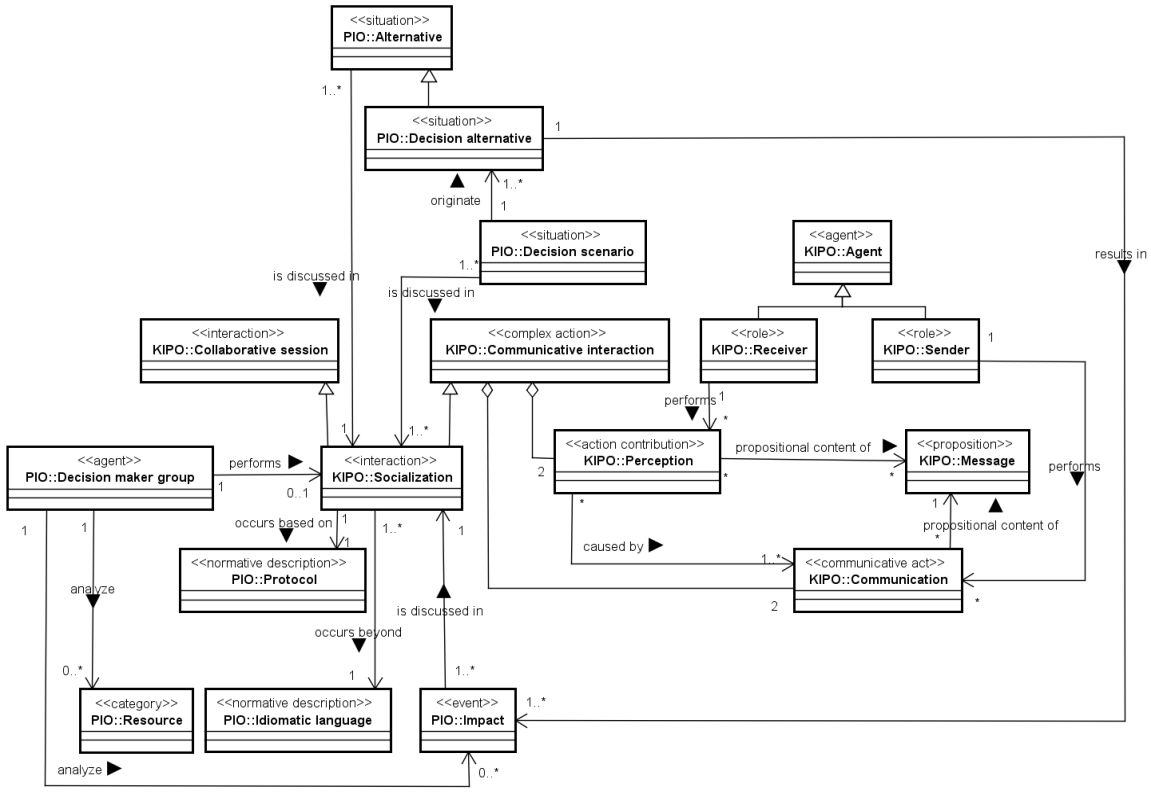

Figure 2: The Collab module.

The decision maker group is composed of decision makers who socialize to discuss the actions inherent in the impact projection activity. It is the role of the decision-maker to analyze the impacts of socialization and to use the available information resources to support the impact projection activities of the decision.

3.3. Complex Decision Process and Activities (PA)

This module of OntoImpact* concerns the impact projection process and the elements that constitute its activities. This module is concerned to understand the dynamic of complex decision and for that discussed the influences of the different types of goals and the activities involved.

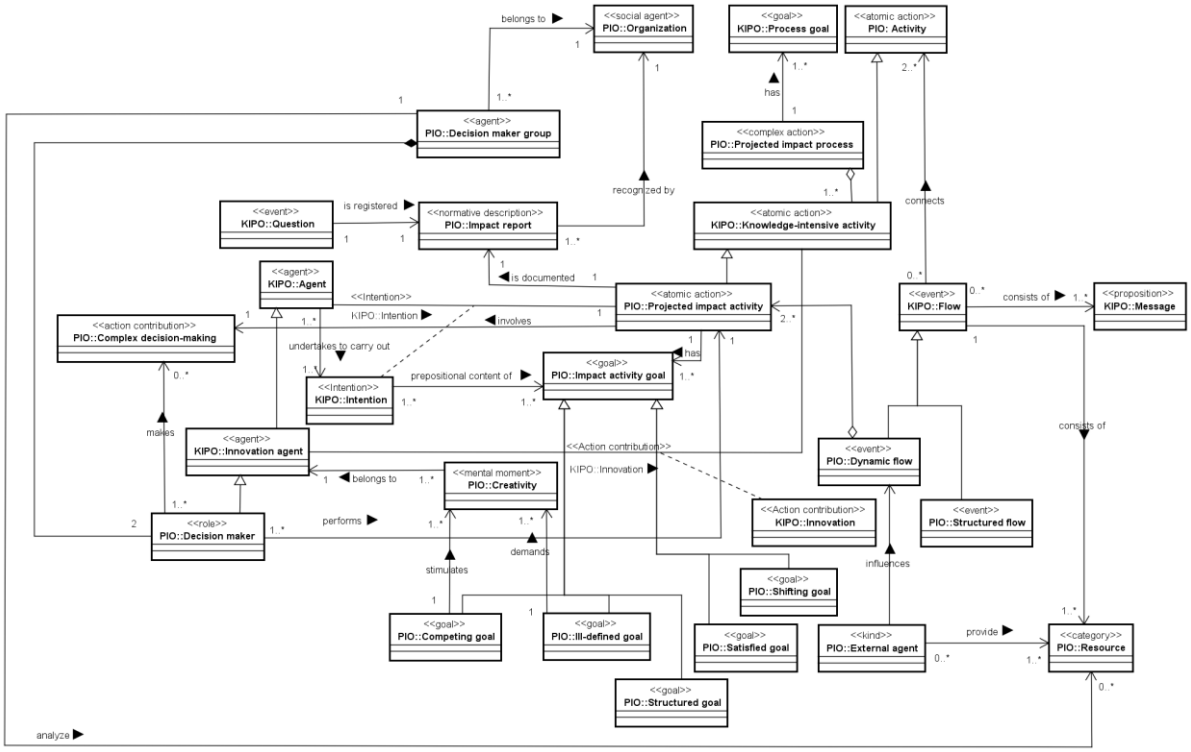

Figure 3: The PA module.

3.4. Structural Elements of Impact Projection (IP)

IP module (Figure 4) presents the structural elements of impact projection and the projection mechanism to project an impact beyond collaborative actions. OntoImpact* present the relations concerned to the concrete concepts like alternative and activities of impact projection, with cognitive aspects.

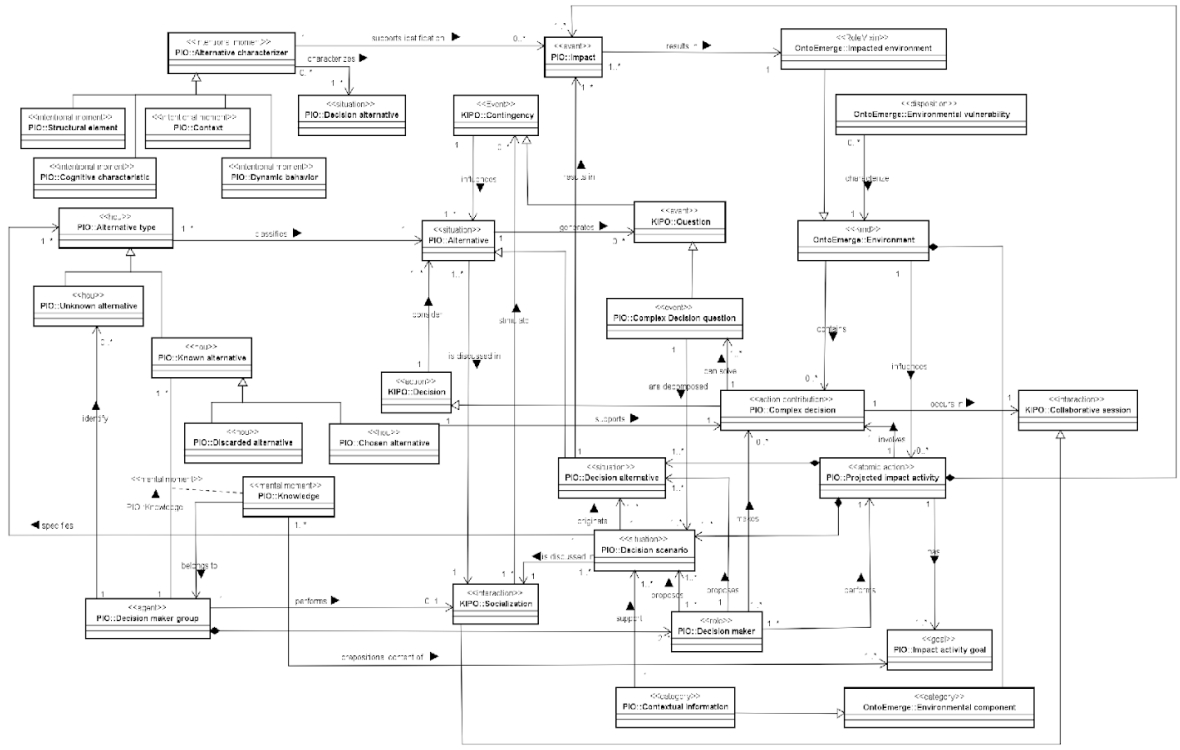

Figure 4: The IP module.

3.5. Impact Detailing (ID)

The ID module describes the concept of an impact and its interactions in the context of complex decisions. This module answered questions related to specificities of impact. For that, this module discussed the relations between events, type of events, risk, and vulnerability for instance.

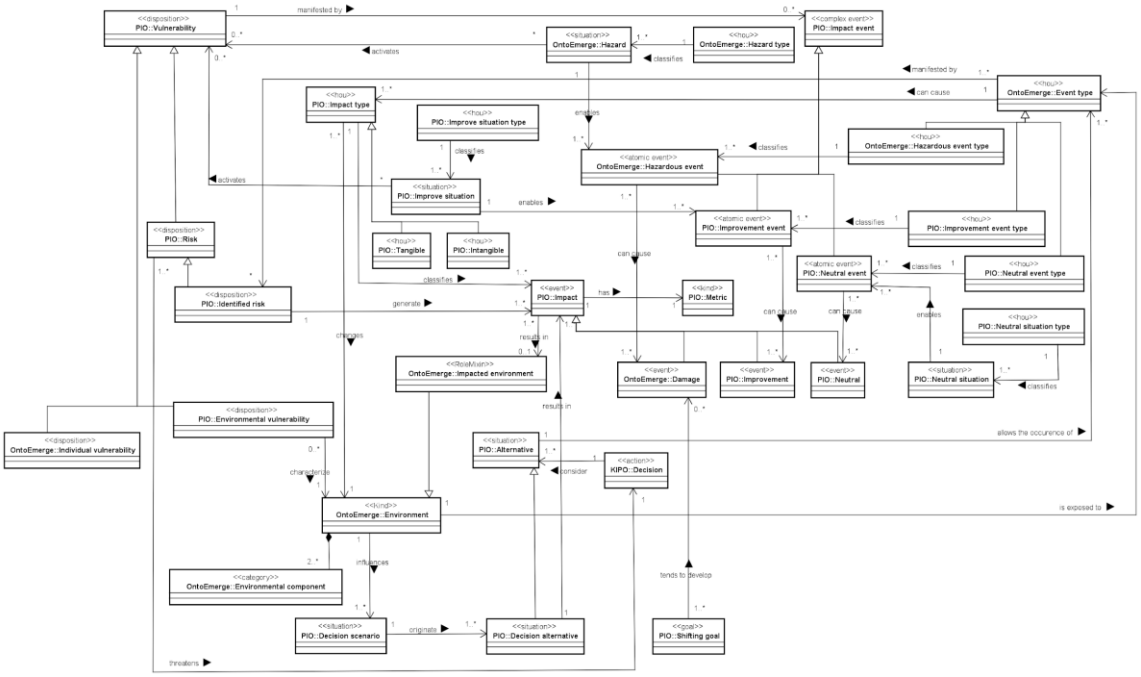

Figure 5: The ID module.

4. Analysis of OntoImpact*

OntoImpact* defines a domain of high complexity that involves the projected impacts of a complex decision dynamics. To achieve results with less ambiguity in terms of the domain, and a better understanding of the impacts of a complex decision and its associated types, this ontology was built based on the methodology and competence questions discussed above, in addition to UFO fundamentals represented into the stereotypes presented in the Figures 1-5.

A UFO is divided into three layers: UFO-A, UFO-B and UFO-C. UFO-A defines the core of UFO, and involves what we call endurants. UFO-B involves perdurants. The difference between these lies in their behavior over time: endurants persist throughout time, such as people and buildings, while perdurants are composed of temporal parts over a period of time. A perdurant can be understood as an event, such as a process, a meeting or a football match. UFO-C involves social entities, such as agents, and their behavioral. It is based on UFO-A and UFO-B. During the development of OntoImpact*, 23 constructs were used from UFO layers. Four constructs from UFO-A were used, based on stereotype, and 19 constructs from UFO-B and UFO-C. The discussion below reflects the formalization of UFO based on several reference elements [8, 12-14, 15, 17, 18, 5].

4.1. UFO-A applied on OntoImpact*

UFO-A involves two categories: universals and particulars. Each particular is understood as an instance of some universal and is also an entity that exists in reality with a unique identity. A universal is defined as a set of characteristics that can be perceived in different individuals. Individuals can assume two types: concrete particular and abstract particular. Concrete individual types are endurant, and are categorized into three types: substantial, mode (or moment), and situation. A situation endurant is an element that represents complex entities made up of several objects or other situations. In this way, the current situation represents a portion of reality that can be understood as a whole [13]. In Figure 5, it is observed that the decision scenario, decision alternative, facts and evidence carry characteristics of the UFO situation. This is because they are known as a portion of reality, bringing the realistic state of the decision-making into scenarios, discussing the possible alternative solutions for decisions and describing their reality, and also what is evidenced in the decision based on facts. The portions of reality defined in Figure 5 form the impact projection defined in the PI module.

The universals act as groups of individuals. There are two types of universals in the UFO-A category: substantial and moment universals. The substantial universals are groups of substantial individuals, and moment universals are groups of moment individuals. UFO-A defines [12] that a substantial universal foresee a specialization in sortal and mixin. The former deals with individuals who have the same identity or principle, while mixin involves individuals with different identity principles.

Sortal universals are classified into rigid, non-rigid or anti-rigid. Rigid sortals bring the rigid semantic charge, that is, an individual who possesses it must continue to have it as long as it exists. For an anti-rigid sortal, the properties of individuals do not necessarily apply to all their instances. The non-rigid sortal is a universal that does not necessarily apply to at least one of its instances. A rigid sortal is divided into four types: kind, subkind, collective and quantity. Kind is understood as a sorcery substance, and its instances are complex natural and artificial functions, such as person, company, desk or computer. The phase and role types are anti-rigid, where a role corresponds to an instantiation of an event or relation participation.

Figure 1 illustrates the concept of a kind in the form of an external agent. A group of decision makers interacts with the outside agent, who is a kind. The external agent presents the same principle of identity and may be another decision maker, expert, or certain objects that are able to provide new inputs to be analyzed. OntoImpact* externalizes role-playing in the interaction between decision makers for the action's execution focused on the impact projection. Figure 2 shows the sender and receiver roles that can be played by a decision maker.

The construct category is a type of rigid mixin that is a universal able to join properties common to different substance sortals, such as the resource concept shown in Figure 1. Here, a resource that is a category can be date or time type. A roleMixin is an externally dependent anti-rigid nonsortal that

aggregates properties common to different roles. Figure 4 shows an example of a reused roleMixin from the OntoEmerge ontology, which is the impacted environment concept.

UFO-A also discusses the concepts of first order universal (FOU) and high order universal (HOU). The former encompasses universals such as a person or animal, whose instances are individuals, while the latter represents universals that have FOU instances. An example of HOU would be a type of tool, for which the instances would be hammer and a sledgehammer. Figure 5 gives examples of HOUs, such as a hazardous event, improvement event, neutral event, improvement situation, and impact. Figure 5 presents concepts defined as HOUs: the type of alternative, and the unknown, known, discarded and chosen alternatives.

4.2. UFO-B applied on OntoImpact*

The UFO-B is dedicated to investigating events (perdurants) and enduring individuals (endurants). Endurants are characterized by being always the same individual, whereas events are composed of temporal parts such as a conversation or a game. In [14], events do not change over time since none of their temporal parts maintains its identity over time.

As events, they transform one situation (presented in UFO-A) into another, altering the state of the represented domain. Events are entities that are existentially dependent on their participants, since they would not exist if there was no participation by substantials. In UFO-B, events can be complex or atomic. Complex events are composed of at least two other events, that are either atomic or complex. In them, their parts add identity to the complex event. Atomic events are indivisible, according to the domain semantics. Examples of the application of an atomic event construct can be observed in Figure 5 through the concepts of hazardous, improvement and neutral events. Each of these contributes to the occurrence of a complex event that may be a damage, improvement, or neutral event. The occurrence of events may enable the manifestation of dispositions in certain situations. In general, objects have properties, some of which are defined as dispositions. A situation allows an event to occur when it activates the mood that is manifested by this event. Figure 5 shows the occurrence of a situation and disposition. Here, a vulnerability is a disposition manifested by the occurrence of an impact event. From this figure, it can be observed that the identified risk, which is an arrangement, plays the role of generating impact that is an event.

4.3. UFO-C applied on OntoImpact*

UFO-C focuses on social concepts involving actions, agents, an intention, a plan, and a commitment. UFO-C has a structure that is based on UFO-A and UFO-B.

Agents in UFO-C can assume one of three types: physical, social or society. In the same way, objects can be physical or social objects. Examples of social objects are organizational rules and norms. A normative description is a type of social object that is able to define rules that are known by at least one social agent. In Figure 3, the impact report is a normative misrepresentation that must be recognized by the organization, in this case behaving as a social object.

Agents are substantial types that may have modes called intentional moments. Each intentional moment has a single proposition as its propositional content. An intention is a subtype of a mental moment, which is a subtype of an intentional moment. From Figure 4, we can observe the occurrence of a proposition assumed by a message; this communicative act has propositional content. When a communicative interaction occurs, it is composed of a communicative act and a perception of this communicative act. Figure 5 shows that agents perform a collaborative session through action contributions, as exemplified through the concept of perception.

Concepts such as belief, desire, and intention (BDI), as discussed in [31], are considered in UFO to be types of mental moment and to inherit the characteristics of the intentional moment that is inherent to each agent. A mental moment is an intrinsic moment that is existentially dependent on a particular agent and is an inseparable part of the agent's mental state. From Figure 1, it can be observed that the concepts of culture, experience, preconceptions, creativity, and feeling are mental moments assumed by agents in the execution of their impact projection actions. In addition to these, agents also assume BDI mental moments in the execution of actions.

Actions and events are distinct elements in UFO-C. An action is caused by the intention of an agent, whereas an event requires the participation of a substantial. It is worth noting that an event is not initiated by participation. In UFO, an agent performs an action based on its commitment to fulfill an intention, with the activity goal as its propositional content. This assumption is illustrated in the AC module of OntoImpact* (Figure 1), in which an agent playing the decision-making role performs impact projection activities based on an intent to achieve the objective of the activity. In an impact projection for a complex decision, decision makers execute a projection activity, which is an action involved in the impact projection process.

An action may be complex or atomic. A complex action is composed of two or more participations, unlike an atomic action. One type of complex action is interaction, which is composed of contributions from different agents, for example in the dialogue between decision makers. An example of this assertion is observed in Figure 2. For socialization to take place, the participation of a decision maker group is required, composed of decision makers playing the roles of sender and receiver. Socialization involves the semantics of the interaction concept.

5. Conclusions and Future Perspectives

OntoImpact* covers the relevant perspectives for a complete conceptualization of impact projection for complex decisions, based on UFO. The main contribution is related to support decision makers into their works tasks, specifically the one that involves decision impacts.

Future work includes the evaluation of OntoImpact*, with special interest in analyzing its completeness and usability to cover the main aspects of impact projection of complex decision. To improve the collaborative session, we plan to develop a technology environment, based on OntoImpact*, to support the impact projection of a complex decision. It is also a future work, improve the OntoImpact* conceptualization through the Core Ontology on Decision Making [16].

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