# Collaborative Construction and Structuring of Explanations in Knowledge-Based Systems: A Discursive Framework

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**Abstract**

Explanations are important to users in a number of situations. They provide knowledge about how the system works, what the system knows and does, and why its actions and recommendations are appropriate. Most of the previous approaches to explanations are designed for those types of knowledge-based systems that attempt to capture the knowledge of a narrow application domain. The current tendency to move beyond closed systems to globally open ones creates opportunities but also some challenges. For example, it is a challenge for designers to cope with the dynamic and global nature of information and knowledge represented in the system as well as to structure explanations at the time of design so that they are appropriate at the time of use. This paper contributes to the current literature on explanation, by presenting a discursive framework for collaborative construction and structuring of explanations. It particularly illustrates how the model can be used for the following purposes: (a) for critical reflection on explanations at the time of design and use, (b) for management of justification-type explanation knowledge, and (c) for presentation of explanations. This paper contents that the discursive model, with its concepts and structures, provides a means for collective reflection, modification and validation of explanation knowledge. It can, thus, support the evolution of explanations along with the knowledge domain.

## Introduction

Explanation facilities are typically included in knowledge-based systems, and in intelligent systems in general, to provide users with the underlying reasons why and how the system reaches a particular conclusion or makes a particular recommendation. Explanations have been shown to improve user's performance and learning and result in more positive user perceptions of the system (Ye and Johnson 1995; Gregor and Benbasat 1999).

Many approaches to explanations are designed for those types of knowledge-based systems that attempt to capture the knowledge of a narrow application domain. Recent developments in the area of knowledge management, which includes knowledge-based systems, raise new issues, and consequently, call for new approaches to explanations. To mention a few challenges: There is a tendency to move beyond closed systems to open systems and to create opportunities for users to participate and to shape the systems (Arias et al. 2000). It is a challenge for designers to cope with the dynamic nature of information and knowledge represented in the system as well as to structure explanations at the time of design so that they are appropriate at the time of use (problem-solving time). There is also a wide agreement on the power of knowledge (and hence explanations) formalized in the system, which may have different consequences for those affected by the system. The aim of a knowledge-management system is to acquire, organize, and communicate knowledge (Alavi and Leidner 2001). Explanations can play their part especially in communication of knowledge. In this context, the existing global differences concerning the assessment of what counts as relevant and valid knowledge or explanations, provide additional conflicts and complications (Yetim 2004).

Many of such challenges speak for "collaborative knowledge-based systems" that allow experts or other knowledgeable actors to dynamically contribute their knowledge to the system and to modify and evolve the system over time. Reflections on and argumentative negotiations of the contents, processes and premises are typical characteristics of collaborative problem-solving systems (Turoff and Hiltz 1995). Explanations and argumentations are often intertwined in such human interaction contexts.

The objective of this paper is to present a discourse model for reflections and to describe how this model can be used in the context of knowledge-based explanations in order to allow modifications of explanations of concepts or relationships, and thus to ensure the evolution of explanations with the knowledge domain. This paper particularly discusses using the model for the following purposes: (a) for critical reflection on explanations at the time of design and use; (b) for management of explanation knowledge, and (c) for presentation of explanations.

This paper is organized as follows. First, some relevant aspects of explanation facilities and current challenges are discussed, and then the discourse model is introduced. Next, the usage options of this model, in the context of

explanations, is illustrated in more detail. Finally, some conclusions are provided.

## Aspects of Explanations in Knowledge-Based Systems

### Purpose of explanations

Since the computer-based explanations of the medical diagnosis system MYCIN (Shortliffe 1976), there seems to be a common agreement that knowledge-based systems should provide explanations to achieve user acceptance and to increase confidence in a system's output. Empirical work confirms the positive impact of explanations on users' acceptance of and trust in the advice provided (Ye and Johnson 1995).

In a number of systems, explanation facilities have been designed to serve several purposes (Yetim 1994; Gregor and Benbasat 1999). For example: (a) to clarify why certain questions were asked by the system if the user does not understand the question or the context, in order to answer the question; (b) to inform or justify how and why specific conclusions were reached or actions recommended; (c) to describe what some terms mean.

In this way, explanation facilities help users to resolve perceived anomalies and to learn about terms and procedures used by the intelligent system. In addition, the use of explanations can be necessitated by particular tasks such as report production or update and debugging of the knowledge-base.

### Designing Useful Explanations

The design of explanations is influential for the usability of explanations since users are unlikely to perceive them as useful when they have to exert too much effort to get them (Gregor and Benbasat 1999).

With reference to the types of explanations designed, previous research on rule-based expert systems has distinguished between *line of reasoning or trace explanations* (i.e. showing a record of inferential steps taken by a system to reach a conclusion), *control or strategic explanations* (i.e. displaying system's control behavior and problem-solving strategy) and *justification* (i.e. describing the rationale behind each inferential step taken by the system) (Chandrasekaran, Tanner, and Josephson 1989; Southwick 1991; Swartout and Moore 1993). In addition, some works use *terminological explanations* (Swartout and Smoliar 1987).[1]

It has been shown that justification-type explanations give rise to more positive user perceptions of a knowledge-based system than trace and strategic explanations (Ye and Johnson 1995). User characteristics, expertise of the user in particular, have been investigated as influencing explanation use and the type of explanations preferred (Mao and Benbasat 2000). The presentation of accessible and appropriate explanations implies that system-generated explanations have to be adapted to the user's knowledge and responsive to the user's needs (Cawsey 1993; Yetim 1994). On the other hand, explanations wrongly tailored to users are probably worse than providing no explanation.

For Swartout and Moore (1993), there are five aspects of good explanations: *Fidelity* (i.e., how accurate is the representation?); *Understandability* (i.e., are the content and context understandable?); *Sufficiency* (i.e., is there enough knowledge to provide explanation in different contexts?); *Low construction overhead* (i.e., how time consuming and difficult is it to build the explanations?); *Efficiency* (i.e., what will the system's response time be?).

The use of explanations is not only influenced by the explanation content but also the by presentation format chosen (text-based or multimedia) as well as by explanation provision strategy (Gregor and Benbasat 1999). Explanations can be designed: (a) to be provided automatically (i.e. always present explanations); or (b) to be made accessible to the user for selection (i.e. hypertext-accessible explanations; or (c) to be presented automatically when the system judges necessary (intelligent explanations).

The most previous explanations have been designed for delivery from the system to a single user, without the user intervening in the explanation construction (Cawsey 1993; Karsenty and Brézillon 1995). Approaches emphasizing the collaborative and interactive nature of explanations regard explanations not as knowledge structures to be transmitted to the users, but as rather qualitatively new structures to which participants of an explanation dialog contribute. In collaborative problem solving, argumentations and explanations are equally used for the resolution of a problem (Hahn 1991). The collaborative aspects of explanation design and its relation to argumentations are of importance for the purpose of the current paper. Therefore, we will explore these aspects in more detail next.

### Explanation as Argumentation

Explanation and argumentation are two relatively close notions and difficult to distinguish. Typically, explanations are initiated by a receiver of information to resolve misunderstandings or disagreements. Explanations may also be initiated by a speaker, or provider of information, with an aim of clarifying, justifying, or convincing. In this sense, an explanation may be viewed in terms of rhetoric or argumentation (Toulmin, Rieke, and Janik 1984). In addition, argumentations and explanations might be viewed as consisting respectively of a forward (from premises to a conclusion) and a backward (from the claim or conclusion

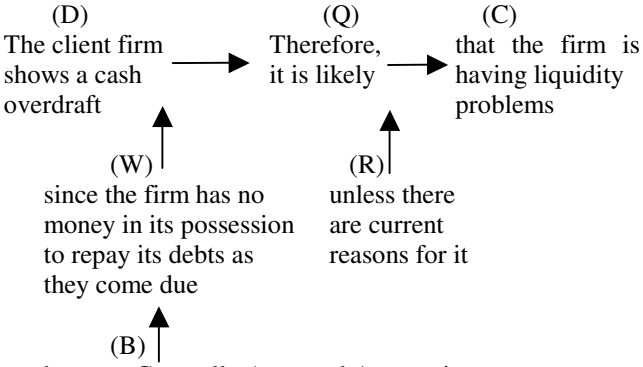
[1]Systems, which are based on newer technologies, such as *belief networks* and *neural networks,* have different internal structures and have more difficulties to explain their reasoning processes to the user.

to the premises) reasoning on the same set of propositions (consult Moulin et al. (2002) for a review).

Toulmin's (1958) model of argumentation, a model of human reasoning, has been used as a basis for constructing explanation capabilities (Hahn 1991; Ye and Johnson 1995). Toulmin distinguishes six elements of an argument:

1. *Claims (C)* – the assertions or conclusions that are put forward for acceptance.
2. *Data (D)* – the statements specifying the particular facts or previously established beliefs about a situation based on which a claim is made.
3. *Warrants (W)* – the statements that justify the inference of the claim from data.
4. *Backing (B)* – the general body of information or experience that assures the trustworthiness of a warrant. Backing is not needed unless the validity of the warrant is challenged.
5. *Qualifiers (Q)* – phrases expressing the degree of certainty placed on a claim. No qualifier is needed if a claim is considered indisputable.
6. *Possible Rebuttals (R)* – extraordinary or exceptional circumstances that might defeat the warranted claim.

The following diagram taken from Ye and Johnson (1995, pp. 161) shows an example of Toulmin's model of argument at work.




Toulmin's model has been used as an explanation structure. A rule-trace explanation, which has a rule with data premise, certainty factor, and conclusion (e.g., "IF *Premise-X* (*certainty-factor-Y* ), THEN *Conclusion-Z"* ), corresponds to the data, qualifier, and claim in Toulmin's model of argument. The *trace explanation* may consist of a chain of invoked rules. The rules encode problem-solving knowledge. However, they do not provide background knowledge that leads a human expert to the rules, i.e. the justification of why a conclusion follows from its premises. In order to integrate knowledge for *justification*, a warrant (W) and possible a backing (B) can be added to the rules. Similarly, explanation knowledge such as explaining the system's problem solving strategy can also be represented (by meta-rules) in order to provide justification or clarification of why the system solves a problem by following a specific procedure (Clancey 1993).

Thus, Toulmin's framework shows where justification for a line of reasoning should be focused, and provides orientation for explanation designers to identify the type of explanation knowledge that needs to be acquired from knowledgeable persons and represented in the system. The argument structure enables the production of explanations at different levels of detail. For example, the structure can be reduced to facts (*evidence, qualifier*) or can also include deeper domain knowledge (*warrant, backing*). As shown later, further meaningfully differentiations between types of explanation knowledge can be made and represented in order to account for various sources and validity aspects of explanation knowledge.

## Towards Globally Open Systems and Some Challenges

As mentioned in the introduction, there is a general tendency to move beyond closed systems to support open, constantly evolving contexts of complex problems. If system developers cannot anticipate and design for every possible situation, systems must be designed for evolution (Arias et al. 2000). In addition, emergent knowledge processes are characterized by highly unpredictable user types and work contexts (Markus, Majchrzak, and Gasser 2002). A knowledge-management system must accommodate complex, distributed, and evolving knowledge-bases and support the dynamically changing process of deliberations and tradeoff. They must integrate expert knowledge with local knowledge sharing.

Consequently, structuring explanations at the time of design so that they are understandable and appropriate at the time of use (problem-solving) is a challenge. Explanations must evolve when the knowledge base of a system evolves. To accommodate users with flexible and appropriate explanations requires the feedback from users of explanations, not only at the time of design, but also at the time of use.

Yet, allowing collaborators to frame and address problem contexts and collaboratively shape explanations involves new challenges to cope with. It means that some of the aforementioned aspects of good explanations (Swartout and Moore 1993) may become an issue of conflicts due to global differences. For example, there may be conflicts about the comprehensibility and relevance of explanations as well as their acceptability for anticipated users or cultural contexts. Explanations justifying the knowledge in the system may be challenged by the users because of the source of the knowledge or its validity in the real world. There is also a wide agreement on the power of the formalized explanation. In socially sensitive domains, real world decisions and their explanations may have

practical – financial, legal, and social – consequences for those affected, and they may be perceived differently, depending on cultural contexts.

Hence, there is a need to link the individual explanations to the social world in order to check their validity as well as acceptability. Such approaches cannot restrict themselves to well-established rules and agreements, rather they need to allow knowledgeable persons or experts collecting and assessing their collective knowledge and their explanations. In the traditional approaches to knowledge-based systems, the construction and coding of the knowledge-base is performed after achieving an agreement among all involved domain experts. Usually, a knowledge engineer or a team of knowledge engineers interfaces to domain experts and accomplishes this. Often, problems arise due to the communication barrier between the knowledge engineer and the experts as well as due to differences in expert's problem solving methods. Moreover, there is not only incomplete agreement among experts, but also agreement and disagreement among experts are themselves evolving properties that change dynamically over time (Turoff and Hiltz 1995).

In what follows, a discursive approach will be presented that aims to accommodate to the dynamic and collaborative nature of explanation knowledge and to provide structures and orientation for the examination of its validity and acceptability.

## The Discourse Model

Figure 1 presents the model for reflection (Yetim 2005). Within this model, two levels are distinguished: the conversation for clarification level and the discourse level.

The *conversation for clarification level* provides an arrangement of some basic issues in form of a staircase. The staircase is an extended version of that proposed by Ulrich (2001). At each step of the staircase conversations for clarification of corresponding issues can take place . The discourse level is entered when controversies arise, which require argumentative examination. The *discourse level* contains several discourses and reflective media proposed by Habermas (1984;1993;1996). They can be seen as places for argumentative examination. The different types of discourses deal with different issues and thus with different types of knowledge. A more informative description and the rationale of the model can be found in Yetim (2005).

The model can support the objective of collaborative knowledge-based systems since its structures allow knowledgeable persons to dynamically contribute their knowledge to the system and to modify and evolve the system over time. In discourses, participants discuss the issue at hand, provide sound arguments to show why a particular claim is supported, and explain certain claims. Communicative action (Habermas 1984) can thus serve as a type of foundation for knowledge because the interaction of ideas with others produces feedback about ideas; Discourses serve - as reality checks against unwarranted assertions - the requirement of consensual agreement about validity. It can thus improve the foundation of knowledge and produce progress in knowledge.

In other words, the model provides a mechanism for a guarantor as required by inquiring systems. According to Churchman (1971), the guarantor determines what constitutes rationality for a given type of inquiry. For some environment the guarantor might be logical proof while for others it might be consensus among alternative options or judgments. Thus, when integrated into the design of knowledge-based systems, the discourse model can support distributed cognition by enabling individuals to represent their understanding, to reflect upon those representations, to question assumptions and understanding. By providing a means for open communication and validation of individual interpretations, the model helps to reduce different types of uncertainty existing in the mind of experts, e.g. uncertainty due to incomplete domain knowledge or uncertainty in the communication concerning the appropriate expressions. In this sense, the model can provide the user of the system with confidence that corroborated knowledge is to enter into the system. Moreover, it may create an awareness of ethical and moral issues and social responsibilities.

Concerning the relation of the model to explanation facilities, it should be mentioned that explanations play a role in discourses when participants justify certain claims. Explanation facilities can support discourse level discussions by providing reasons related to the clarification level issues. For example: providing physical, syntactic, and semantic reasons for explaining communication breakdowns or for justifying recommendation for achieving comprehensibility; or justifying why an expression or action is relevant, trustworthy, normatively right, or efficient. In what follows, the focus of attention will, however, be limited to the role of the model within the context of knowledge-based explanation facilities.

## The Role of the Model in the Context of Explanations

The model can be used for the following purposes, each of which is discussed next: (a) for critical reflection on explanations; (b) for management of explanation knowledge; and (c) for presentation of explanations.

### Reflection on and Negotiation of Explanations

The model provides a structure for collaborative construction of explanations. It offers orientation for actors for reflection on and discursive evaluation of explanations. At the conversation for clarification level, the staircase provides a taxonomy of breakdowns and thus make explicit on what aspects of explanations need to be

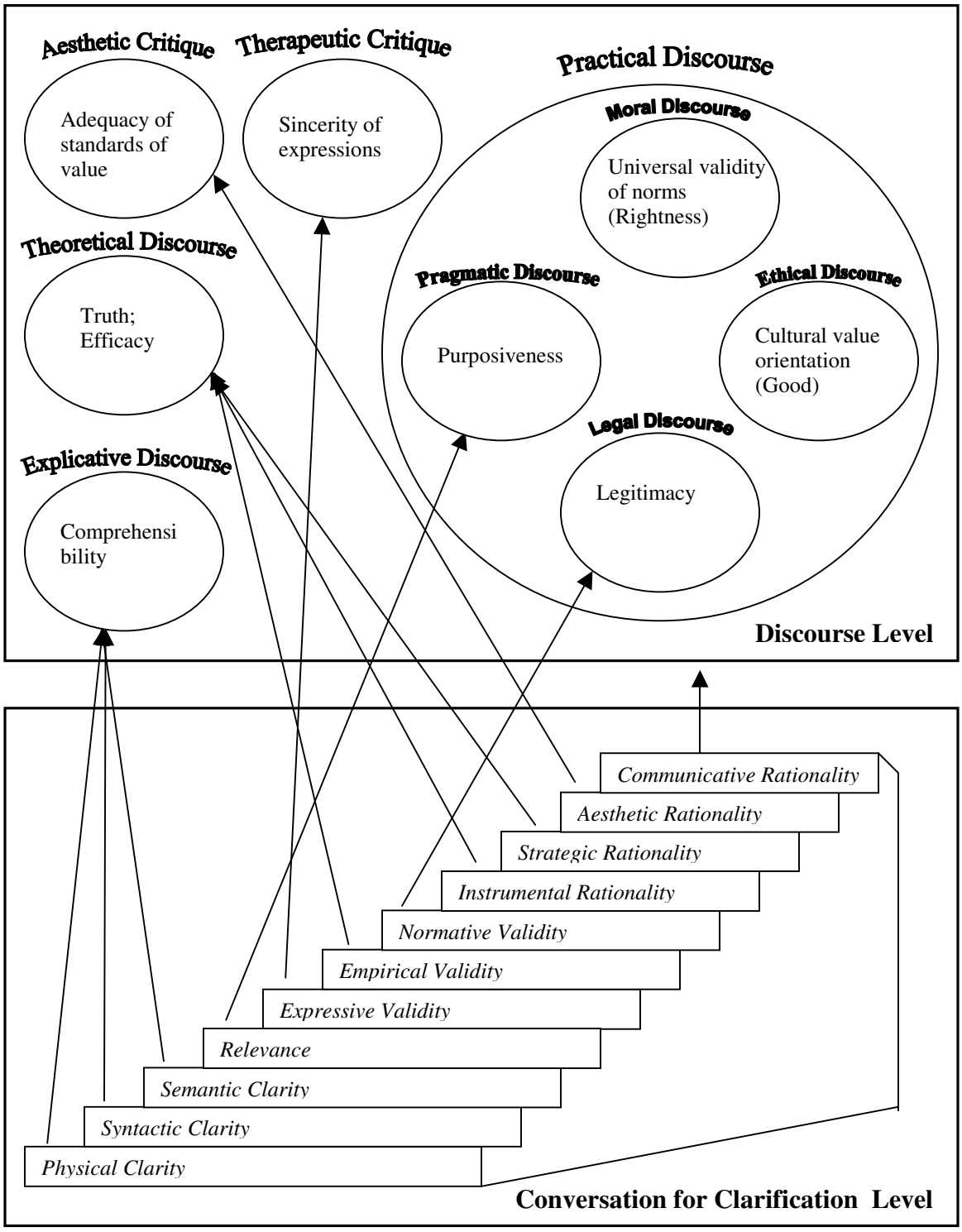



Figure 1: The Discourse-Based Model for Reflection

reflected. The breakdowns range from technical issues to syntactic, semantic, and relevance aspects of the explanation content to its validity, appropriateness, and effectiveness in an interaction situation. Since disagreements at the conversation for clarification level are argumentatively examined in related discourses, argumentation in discourses serves explanations.

For example, conversations for clarification can be triggered if the media used are not appropriate for the presentation of an explanation (physical clarity) or the dependency or the meaning of the parts of an explanation is not clear (syntactic, semantic clarity). Actors may also challenge the comprehensibility of current expressions in other cultural contexts (e.g., "X means Y in the cultural context Z"). Thus, at the first three steps, actors can reflect on the clarity of explanations with respects to their physical, syntactic, and semantic aspects, and may argumentatively resolve disagreements in explicative discourses. Similarly, the relevance of an explanation or its parts can be subject to clarification if it does not serve the purpose of explanation or considered as irrelevant for the anticipated users.

Concerning the clarification of the validity of explanations, expressive validity refers to clarifications on whether an explanation reflects sincere intentions (e.g., "do we really mean that?" "whose explanation is that? That of human or software agent?"). Breakdowns may also occur due to the intentional exclusion of some contrary facts of the case in order to immunize a certain explanation. Empirical validity refers to the truth of explanations (e.g., "is there any incorrect or incomplete evidence postulated in the explanation?"). The normative validity step deals with the clarification of whether explanations are in accord with accepted laws, rules or norms (e.g., "is it appropriate/allowed in this context to justify the exclusion by reference to ethnic identity?").

The rationality of explanations can be clarified as well. The design of explanation can be assessed according to its instrumental rationality, i.e. the efficiency of its design. Strategic rationality refers to the clarification of whether an explanation is strategically effective. Aesthetic rationality concerns aesthetical aspects of explanations. This is especially important for multimedia explanations. Finally, the communicative rationality refers to the communicatively achieved agreement among actors with respect to different aspects of explanations. Actors reflect in this step on what they have achieved so far.

To conclude, the model can be used to support collaborative construction of explanation at the time of design as well as critiquing and revision of explanation knowledge at the time of use. The staircase with eleven steps explicitly or implicitly includes the five good aspects of good explanations, as suggested by Swartout and Moore (1993) and also mentioned earlier, but also goes beyond them. Reflections on these aspects and renegotiation of them can contribute to the evolution and continuous improvement of explanation knowledge, along the improvement and dynamicity of domain knowledge. To use the model online for allowing critique requires the implementation of the model as parts of user interfaces. A discussion of implementation options can be found in Yetim (2005).

## Management of Knowledge Related to Explanations

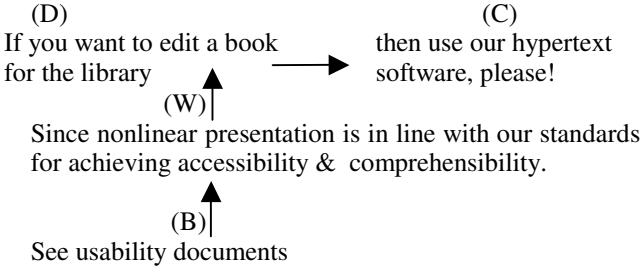
The model can also provide orientation to structured management of explanations in the knowledge base. Usually, a collaborative knowledge-based system has to deal with many types of knowledge. Discourses serve for the validation and legitimating of different kinds of knowledge. Thus, explanation designers may categorize knowledge related to explanation according to the logic of issues addressed in discourses.

According to Toulmin et al (1984), the warrants derive their foundation and authority from backing of quite different sorts. The backing of any argument defines the argument-field to which that argument belongs. In what follows, we consider the discourses to classify different kind of knowledge, and use Toulmin's model of argument to illustrate how these knowledge-types can be used as warrants to justify system's actions or recommendations.

**Communication Knowledge (Explicative Discourse)** Explicative discourse is the place where the comprehensibility of signs with respect to their physical, syntactic, and semantic aspects is discussed. We use the notion of communication knowledge to refer to knowledge about how to communicate perceivable, interpretable and thus comprehensible way.

There are many general communication strategies, such as abstraction, precision, using metaphors, etc., as well as language strategies in intercultural communication. Communication knowledge also includes guidelines for avoiding terminological confusions in international communication (e.g., international English), grammar, or differences in syntactic conventions, as well as guidelines for producing universally usable explanations that take technological differences into account. They can be expressed in the form of maxims. This type of knowledge can be used to justify the communication of the systems output (its result or recommendations) to the user, but also the communication of explanation knowledge itself (e.g., "if situation-X, then use term-Z"). In the latter case, it is strongly related to the explanation generation component of the systems and provides guidance for the generation of comprehensible explanations.

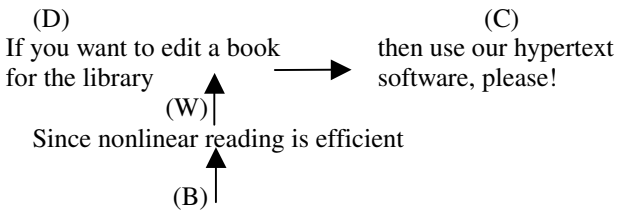
The following example illustrates the justification (*warrant*) of the system's recommendation from a communication point of view.



In answering a user's question *why*, the system can provide the justification from this perspective by following the response steps.

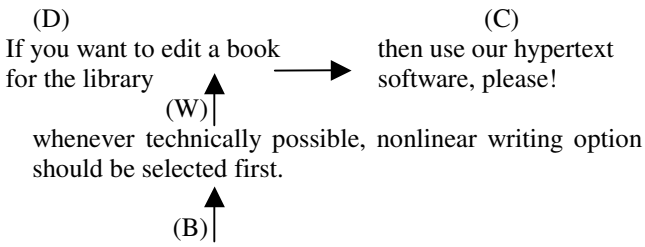
**Theoretical Knowledge (Theoretical Discourse).** In theoretical discourse, the truth of propositions and the efficacy of actions are justified. Theoretical discourse includes both analytic-empirical discourse and cognitive-rational discourse. Hence, we use the notion of theoretical knowledge to refer to scientific theories, laws of nature, mathematical structures, mechanistic principles, historical regularities or the like. They can serve as warrants and rest on adequate experimental evidence or other observations.

The following example illustrates a scientific justification of the same claim.



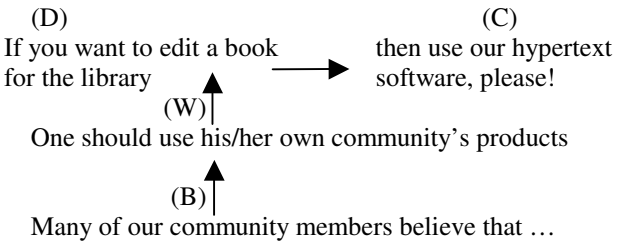

**Pragmatic Knowledge (Pragmatic Discourse).** Pragmatic discourse deals with the rational assessment of means in the light of fixed goals or, if the goals themselves are problematic, with the rational assessment of goals in the light of existing preferences (values). Thus pragmatic discourses justify and recommend appropriate techniques or strategies, i.e. specify what to do when faced with a particular problem.

Typically, rules expressing purposive-rational choice of means (techniques, strategies) or value-oriented weighing of goals can serve as warrants. For example:

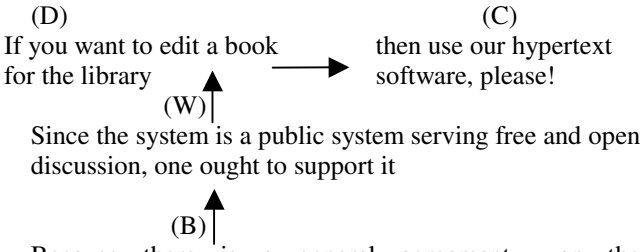



**Ethical Knowledge (Ethical Discourse).** Ethical considerations deal with issues of "good" and "bad". Ethical knowledge provides orientation in the social world, but only within the horizon of a specific culture. Every cultural community has its own particular ideas of good and bad. Certain kinds of actions and/or consequences are perceived as being desirable to a greater or lesser degree.

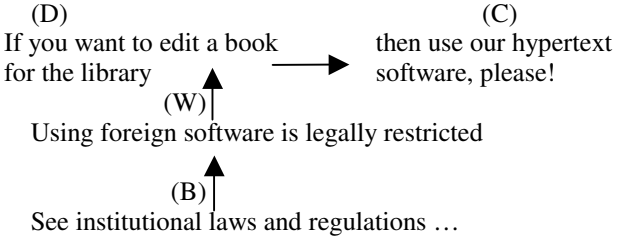
In knowledge-based systems, ethical knowledge can be modeled as values shared by groups. Community-specific values can serve as warrants to justify an action or recommendation from an ethical point of view. For example:



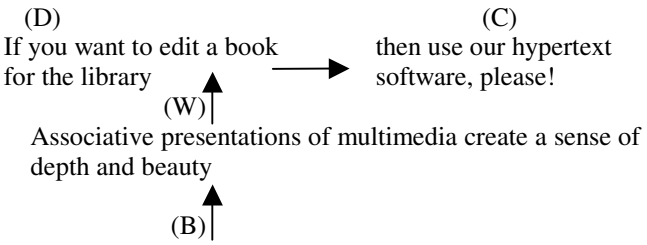

**Moral Knowledge (Moral Discourse).** Moral discourse is concerned with justification and application of norms that stipulate reciprocal rights and duties. In contrast, to ethical knowledge, moral knowledge raises a claim to universal validity. Moral knowledge is handed down in the form of moral ideals or maxims. In contrast to ethical considerations, which deal with issues of good and bad, moral issues are concerned with right and wrong, i.e. deal with consideration of justice (Habermas 1993). A heuristic for generating maxims can be guided by the question of whether an action is good for a group of users, and thus recommended (ethical perspective), or whether it ought to be followed by everyone, i.e. ruled out as being *categorically* acceptable or unacceptable (moral perspective). For example:



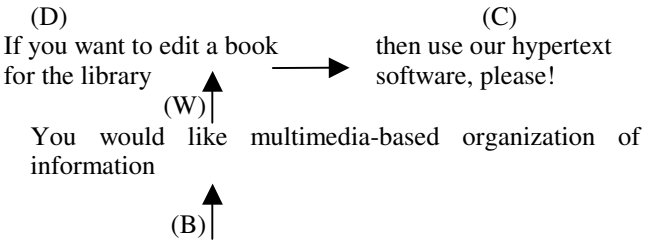

**Legal Knowledge (Legal Discourse)**. Legal discourse deals with the legitimacy of rules, laws etc. Hence, administrative regulations, laws, statutes, and so on can serve as warrants. For example:




**Aesthetic Knowledge (Aesthetic Criticism)**. Aesthetic criticism is concerned with the adequacy of the standards of value presented in works of art (Habermas 1984). Knowledge about aesthetical values, interpretations or expectations of people can serve as warrant for justifying results, actions, or recommendations. For example:




**Personal Knowledge (Therapeutic Critique)**. Therapeutic critique addresses the sincerity of expressions. Knowledge about private preferences, beliefs, assumptions of a single person can serve as warrants for justifications. For example:




To summarize, the different type of discourses provide orientation for the segmentation of justification knowledge, which is added as warrants to rules for explanation purposes. By doing so, a system can provide justification for its recommendations from different perspectives. Depending on the contexts, the most appropriate justification needs to be selected. Note that these simple examples are chosen for explanatory reasons. In line with the philosophy of the proposed approach, they are open to critique or revision.

### Presentation of Explanations

The third usage option of the model concerns the model's guidance for presenting explanations. The staircase provides a taxonomy of breakdowns that may occur when a system acts and may lead to user questions. Using the steps of the staircase, the system can thematically organize the presentation of explanations to its current action (e.g. to a recommendation made or to a result calculated). By doing so, the system implicitly responds to various types of user questions. Depending on the amount of explanation knowledge available in the knowledge-base, each step (or combinations of steps) can also be treated as a hypertext node, containing corresponding explanation knowledge.

For example, in a single node the system may present explanation knowledge that provides clarifications for the purpose of comprehensibility. Similarly, another node may contain justifications of why the system considers something relevant or purposeful. Clarification of validity aspects can be presented as a single thematically related node, including for example, the source of the information, its trustworthiness and truth or legal aspects. Finally, explanations related to the rationality aspects can be grouped into a single node, showing, for example, how the system achieved the result (e.g., presenting a trace), which strategy it used (e.g., highlighting the chosen strategy), weather aesthetical reasons played a role, and what degree of agreements among experts are available on the corresponding explanation item (norms or other concepts).

Generally, hypertext-like structures provide the opportunity for flexible organizing and presenting of explanations, i.e. the elements of explanations can be linked together and be followed quickly and easily (Yetim 1993;1994). Whether each single step of the staircase or some combination of them is appropriate depends on the amount of explanation knowledge available. In any case, the steps of the staircase can provide orientation.

## Conclusions

This paper has discussed the role of a discursive framework for satisfying the requirements of explanations in open and collaborative knowledge-based system contexts. As illustrated, it provides orientation for the management of explanation knowledge as well as for reflection on and presentation of explanations. The discourse model provides a mechanism to validate the explanation knowledge in the system. Accordingly, as demonstrated, justification knowledge can be meaningfully organized using this framework. It allows actors to challenge, negotiate, revise the warrants and their backing in corresponding discourses. In this way, it can support the evolution of explanation knowledge with domain knowledge. An interesting aspect of this approach is that it allows the critique of explanations. The systematic critique of explanation has not gained much explicit attention in the previous approaches to explanations and deserves further attention in future works.

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