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Collaborative Modeling: Towards a Meta-model for Analysis and Evaluation

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Abstract

In this paper we discuss a meta-model for the analysis and evaluation of collaborative modeling sessions. In the first part of the meta-model, we use an analysis framework which reveals a triad of rules, interactions and models. This framework, which is central in driving the modeling process, helps us look inside the modeling process with the aim of understanding it better. The second part of the meta-model is based on an evaluation framework using a multi-criteria decision analysis (MCDA) method. Central to this framework, is how modelers' quality priorities and preferences can, through a group decision-making and negotiation process, be traced back to the interactions and rules in the analysis framework. The meta model not only helps us find out what takes place during the modeling process but also the quality of the different modeling artifacts used in, and produced during, the modeling process. Illustrative examples, from real modeling sessions, are given to demonstrate the theoretical significance and practical importance of the meta-model.

Keywords: Collaborative Modeling, Modeling Process Quality, Modeling Process Analysis, Modeling Process Evaluation, Group Support Tool

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1. INTRODUCTION

The aim of system (re-)engineering is to improve the way that organizations or enterprises operate. Normally, this involves building system models which represent a set of existing operations of an organization with its inherent limitations or a new set that is likely to overcome the identified system constraints. To build such system models, collaborative modeling (Barjis, 2009; Rittgen, 2007}, which is conceptually similar to group model building (Andersen et al., 2007; Vennix, 1996), is often employed by a team of stakeholders - end-users or domain experts, systems analysts, model builders, systems engineers, etc. Normally, such a problem-solving activity is aided either by a professional facilitator or a practitioner who may employ a group support system (GSS) tool (Dean, et al. 1994). As argued by Nunamaker et al. (1991), the combination of the facilitation and tool support renders the collaborative problem solving activity to be done in a chauffeured, supported or interactive manner in which individual or group participation, tool support or human communication predominates.

Human communication, in collaborative modeling, involves argumentation, negotiation and decision making. Negotiation and decision-making require collaborative modelers to reach consensus and agreement on a number of issues, a process which will succeed if modelers draw upon their skills and competencies. Often, participants need to agree, through negotiation and decision making, on what constitutes, for example, “quality” for the different modeling artifacts used in, and produced during, the modeling session and how such quality should be measured or evaluated. To effectively measure and evaluate the quality of the modeling process, however, there is a need to first study and understand what generally takes places during the modeling process. Understandability demands looking at a number of things including, though not limited to, modelers' interactions, conventions or guidelines governing the modeling process, the products (intermediate and final), etc. Initial attempts, to try to understand modeling, were made by Veldhuijzen (2004) where modeling is looked at as being driven by participants' communication. Recently, there have also been some attempts to study and analyze the modeling process (Rittgen, 2008) where modeling is seen to be mainly a negotiation process.

However, how to analyze, measure and evaluate the collaborative modeling process, especially its effectiveness and efficiency with respect to the modeling artifacts, remains a largely unexplored area. Additionally, methods and/or tools that can help us trace and reveal what took place during the modeling session, and how to evaluate the quality of the modeling artifacts used in and produced during, the modeling session are rare. The intent of this article is, therefore, to make an initial attempt in developing methods and techniques to achieve this objective. More specifically, the current paper tries to develop a meta-model which can be used for both the analysis and evaluation of a collaborative modeling process and the relation between events in the process and the resulting artifacts. The meta-model links the modeling artifact and the evaluation framework to the RIM framework through the interactions which are governed by rules. Through this meta-model, we are able to improve the process in order to improve the results or to diagnose the process in view of insufficient results.

2 MODELING PROCESS ANALYSIS: THE RIM FRAMEWORK

There have been attempts to analyze collaborative problem solving activities, especially with regard to modelers' dialogue and interaction, for better understanding the mechanics of collaboration (see for example, (Avouris, 2003)). However, much still needs to be done to identify the interplay between the interactions, the rules governing these interactions and the products obtained in such interactions under such governing rules. In order to explore this, there is a need to look at how stakeholders in a collaborative modeling session combine their skills and competencies, expertise and knowledge in order to perform some modeling task. All activities prior to, and during, the collaborative modeling session are driven by communication which plays a central role, see for example, (Clark, 1991). This communication and the different interactions that result need to be analyzed in view of the rules governing the whole process and the outcomes produced.

Stakeholders, in a collaborative modeling process, interact and communicate their ideas and opinions to other members through the communication process. Three key items concerning this communication are the rules that drive the modeling process, the interactions as a result of the communication and the products generated (see for example (Ssebuggwawo et al., 2009)). The rule, interactions and models (RIM) framework is based on these items and helps us look into the collaborative modeling process. This framework is depicted in Figure 1. The interplay of rules, interactions and models is explained in Table 1.

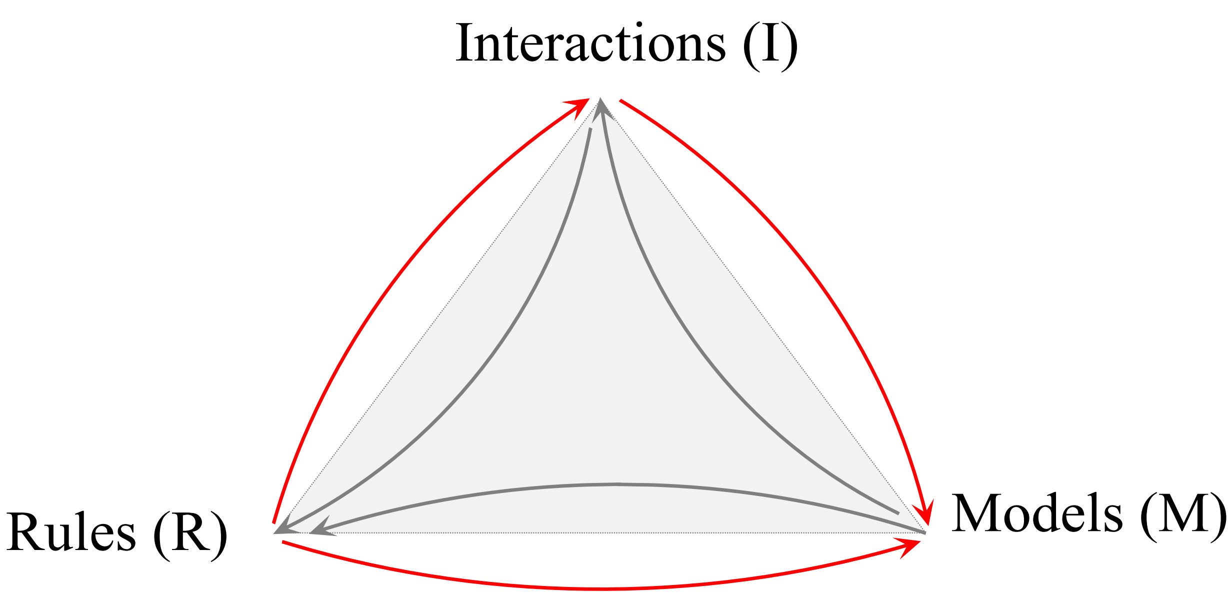


Figure 1. A framework for analyzing interactions, rules and models

Table 1. RIM framework features

Path	Interplay
IM-MI	The interactions lead to the generation of models and generated (intermediate) models drive further interaction.
RM-MR	Some rules/goals of modeling apply to (intermediate) models and these models may lead to the setting of new rules/goals.
RI-IR	Rules guide and restrict interactions and some interactions may change the rules of play.

2.1 Interaction Analysis: The Structure

In order to analyze the interactive conversations and determine the structure of the speech-acts that result thereof, we need to apply a discourse analysis or conversation analysis technique. There are a number of methods which can be used, notably, speech-act theory (Searle, 1969). However, as argued by Winograd and Flores (1986), speech-acts are individual statements in the whole conversation and cannot be analyzed outside the whole conversation in which they occur. The language-action perspective (Goldkuhl, 2003) is, therefore, a candidate in analysing the whole conversation in which the speech-acts are just components. Figure 2 shows the structure of the interactions. We use *Object Role Modeling (ORM)* method (Halpin, 2001) to represent analysis and evaluation concepts in this paper. Table 2 shows the elements of the interaction component.

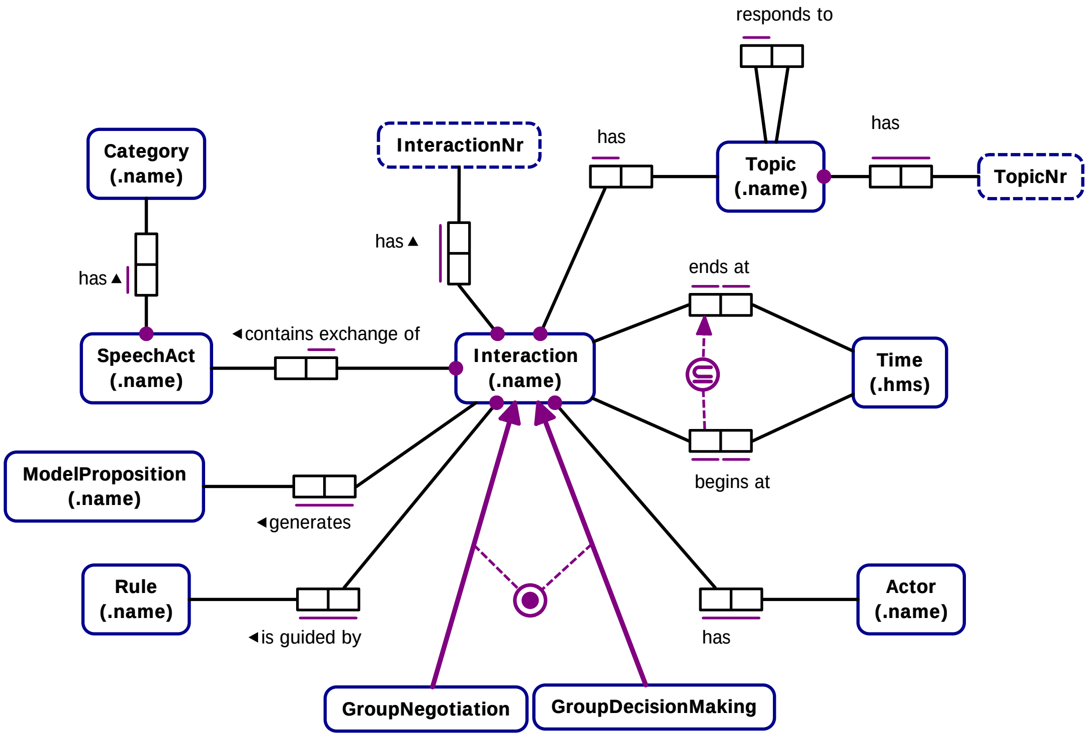


Figure 2. Elements of an interaction

Table 2. Explanation for elements of an interaction

Element	Explanation
InteractionNr	Unique number that refers to an interaction.
Time	Time at which an interaction is (de-)activated.
Topic	Subject under discussion in an interaction with a topic number.
Actor	A participant in an interaction.
Speech-act	An illocutionary act from the interaction and has a category.
ModelProposition	Proposition (Implicitly or explicitly agreed to) that constitutes model formation.
Rule	Guideline(s) or convention(s) that direct the interactions.

2.2 Rule Analysis: The Structure

Rules govern the interactions and production of the models. They guide collaborative modelers during the modeling process and can be set for (before) or in (during) the modeling process. They forth and back link the product of the conversations - the model to the conversations and they are intended to guarantee both process quality and model quality. There is a special type of rule that sets the states to strive for-called the goal rule. Rules are either explicitly stated or implicitly stated. The elements of a rule are given in Figure 3 while Table 3 explains these elements.

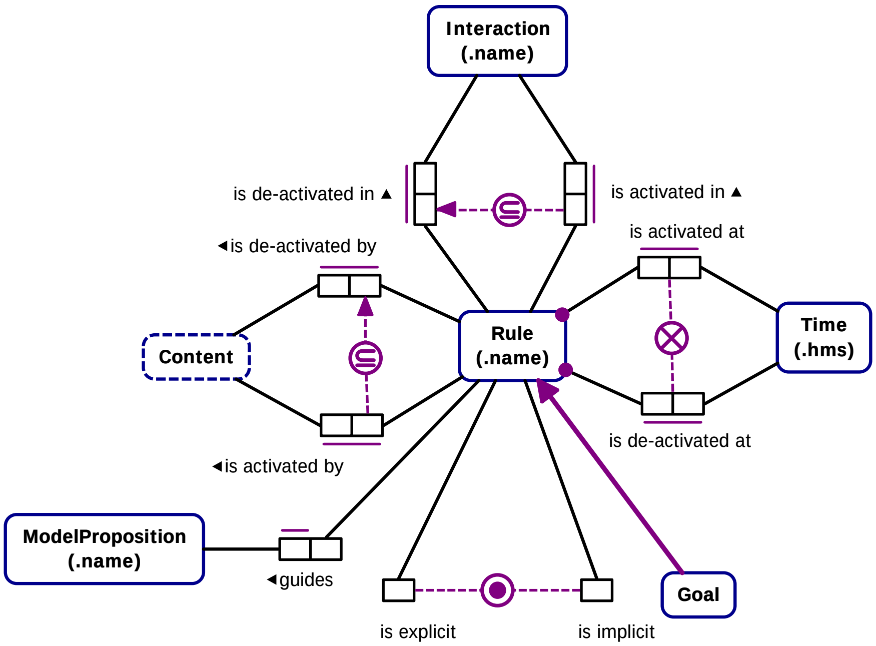


Figure 3. Elements of a rule

Table 3. Explanation for elements of a rule

Element	Explanation
Content	Conversational content in which a rule is (de-)activated.
Time	Time at which a rule is (de-)activated.
Interaction	Conversations from which propositions are generated.
ModelProposition	Proposition (Implicitly or explicitly agreed to) that constitutes model formation.
Goal	A rule that sets the state to strive for.

2.3 Model Analysis: The structure

Models (intermediate or final) are lists of propositions up to time t, i.e. conversational statements commonly agreed upon and shared by all the modelers. These model propositions are subject to selection criteria in order to determine which one makes it to the group (shared) model. In collaborative modeling a model proposition is either explicitly agreed with or implicitly not disagreed with. The structure of a model proposition component is shown in Figure 4 while its elements are explained in Table 4.

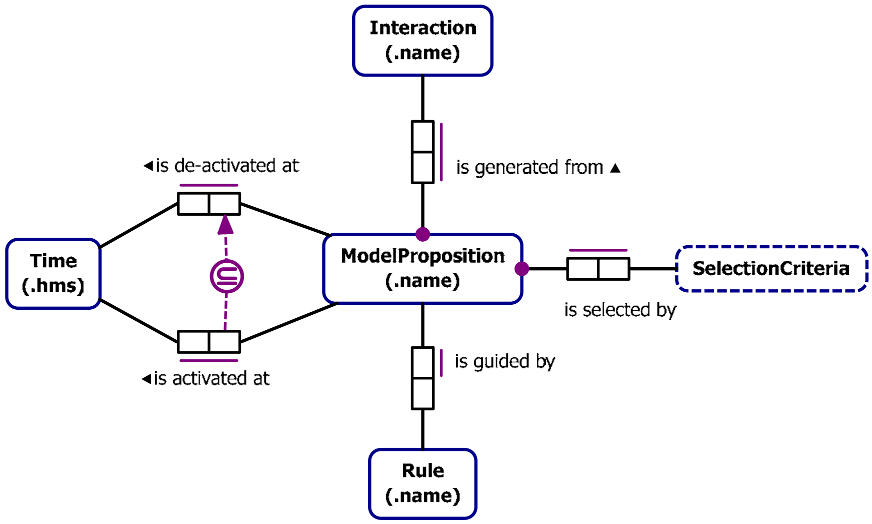


Figure 4. Elements of a model proposition

Table 4. Explanation for elements of a model proposition

Element	Explanation
Rule	Guidelines that direct the selection of a model-proposition.
Time	Time at which a model-proposition is (de-)activated.
SelectionCriteria	A set of evaluation criteria used to select a model-proposition
Interaction	Interaction from which a model-proposition is generated.

3 MODELING PROCESS EVALUATION: AN MCDA FRAMEWORK

In collaborative modeling a number of artifacts are used in, and produced during, the modeling process. These include the modeling language, the methods or approaches used to solve the problem, the intermediate and end-products produced and the medium or support tool that may be used to aid the collaboration, see for example (Ssebuggwawo et al., 2009). The priorities of the individual decision makers need to be aggregated, so as to reach agreement and consensus on what should be the group's position as far as modeling process quality is concerned. Reaching agreement requires group decision making and negotiation. It is on this basis that we use a Multi-criteria Decision Analysis (MCDA) method to evaluate the modeling artifacts.

3.1 Selecting an MCDA Method

Selecting a particular MCDA method requires the decision makers, i.e. collaborative modelers, to know the different MCDA methods available. These methods can broadly be categorized in two main classes : continuous and discrete methods (Guitouni & Martel., 1998). Continuous methods have a finite and explicit set of constraints in the form of defined functions that define an infinite number of alternatives to consider in the evaluation and decision making process. Discrete methods, on the other hand, have a finite number of alternatives normally defined in tabular form with their corresponding evaluation criteria. The decision making problem we study in collaborative modeling belongs to the discrete case.

There are three approaches from which to choose an MCDA method: *(i) single synthesizing (weighting) criterion preference approach* - with Analytic Hierarchy Process (AHP) (Saaty, 1980); Multi-attribute Utility Theory (MAUT), Multi-attribute Value Theory (MAVT) and Simple Multi-attribute Rating Techniques (SMART) (Keeney & Raiffa, 1976) as representatives, *(ii) outranking synthesizing preference approach* - with the "Elimination Et Choix Traduisant la Realite (ELECTRE)", i.e. Elimination and Choice Expressing Reality methods (Roy, 1991) and the Preference Ranking Method for Enrichment Evaluation (PROMETHEE) methods (Brans & Vinckle, 1985) as the most prominent representatives, and *(iii) interactive local-judgement preference approach* - with the Multiple Objective Mathematical Programming Methods (MOMP) (Narula et al., 2003) as the most prominent representatives.

3.2 The MCDA Evaluation Framework

The evaluation of the modeling artifacts involves interactions between and among the modelers, mainly using group negotiation and decision-making on part of the modelers due to personal priorities and preferences which need to be reconciled. To determine the quality of a modeling artifact, participants have to identify the features or characteristics to be scored in order to establish its quality. These features form a set of quality criteria for each evaluated modeling artifact. The quality criteria are scored, i.e. given quality scores either individually or collectively by the group.

Group scores are as a result of aggregating individual scores. These quality (individual and group) scores are used in the computation of the priorities which are finally used to determine the individual and group preferences-thus determining the overall quality of the modeling artifact.

The structure of the evaluated modeling artifact component, within the MCDA evaluation framework, is shown in Figure 5. The different concepts are explained in Table 5.

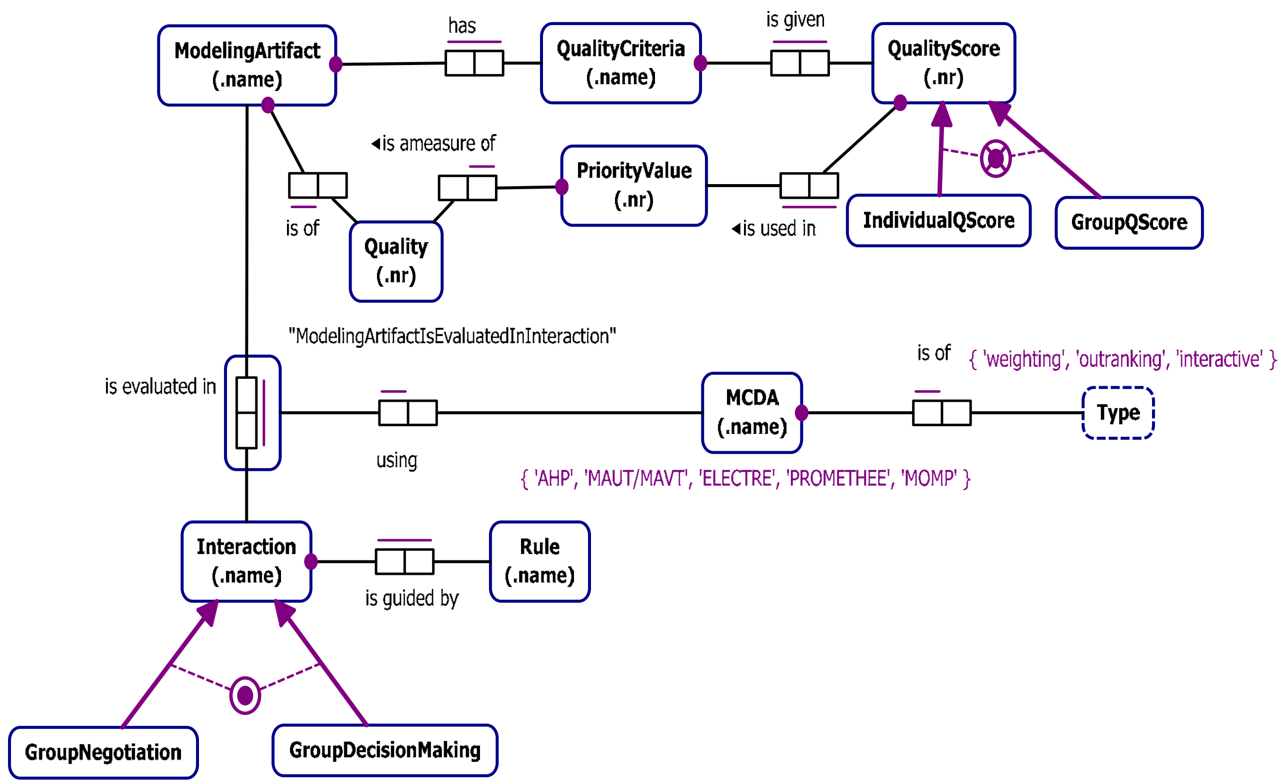


Figure 5. Elements of a modeling artifact

Table 5. Explanation for elements of a modeling artifact

Element	Explanation
Quality	Degree of excellence or deficiency-free state.
QualityCriteria	A modeling artifact feature to measure quality.
QualityScore	A value given to a criterion as a measure of its quality. It may be an individual or group score.
PriorityValue	Aggregated quality scores to determine priority values.
Interaction	Group negotiation/decision-making to agree on quality scores.
Rule	A set of guidelines that direct the interactions.
MCDA	A multi-criteria decision analysis approach used for the evaluation. It is of a certain type.

One important observation about the modeling artifact and the evaluation framework is the link provided by the evaluated modeling artifact to the RIM framework through the interactions which are governed by rules. This is an important observation since it helps us to unify the two frameworks. In the next section we develop a meta-model that unifies the analysis (RIM) framework and evaluation (MCDA) framework. The meta-model helps us to improve the modeling process in order to improve the results or to diagnose the process in view of insufficient results.

4 THE ANALYSIS AND EVALUATION META MODEL

In Sections 2 and 3 we have identified the different components for the analysis and evaluation of collaborating modeling. However, these components present a fragmented view for analysis and evaluation of the modeling process. In this section we combine the components to form a unified model for the integrated analysis and evaluation (of process and results) of collaborative modeling. The components are linked together in a meta-model shown in Figure 6.

The novelty of the meta-model is that it combines the analysis and evaluation frameworks, i.e., the RIM framework and the MCDA framework. This is easily visible in the meta-model where the triage of the rules (R), interactions (I) and models (M) in Figure 1 is depicted through the rules, interactions and model proposition entities. The centrality of communication in collaborative modeling is visible in the meta-model through the role played by the interaction in linking the two frameworks. This is evident from the way the modeling artifact evaluated in the MCDA evaluation framework is linked to the RIM framework via this interaction. The objectified predicate "*Modeling-Artifact-Is-Evaluated-In-Interaction*" provides the link to the interaction in the RIM Framework.

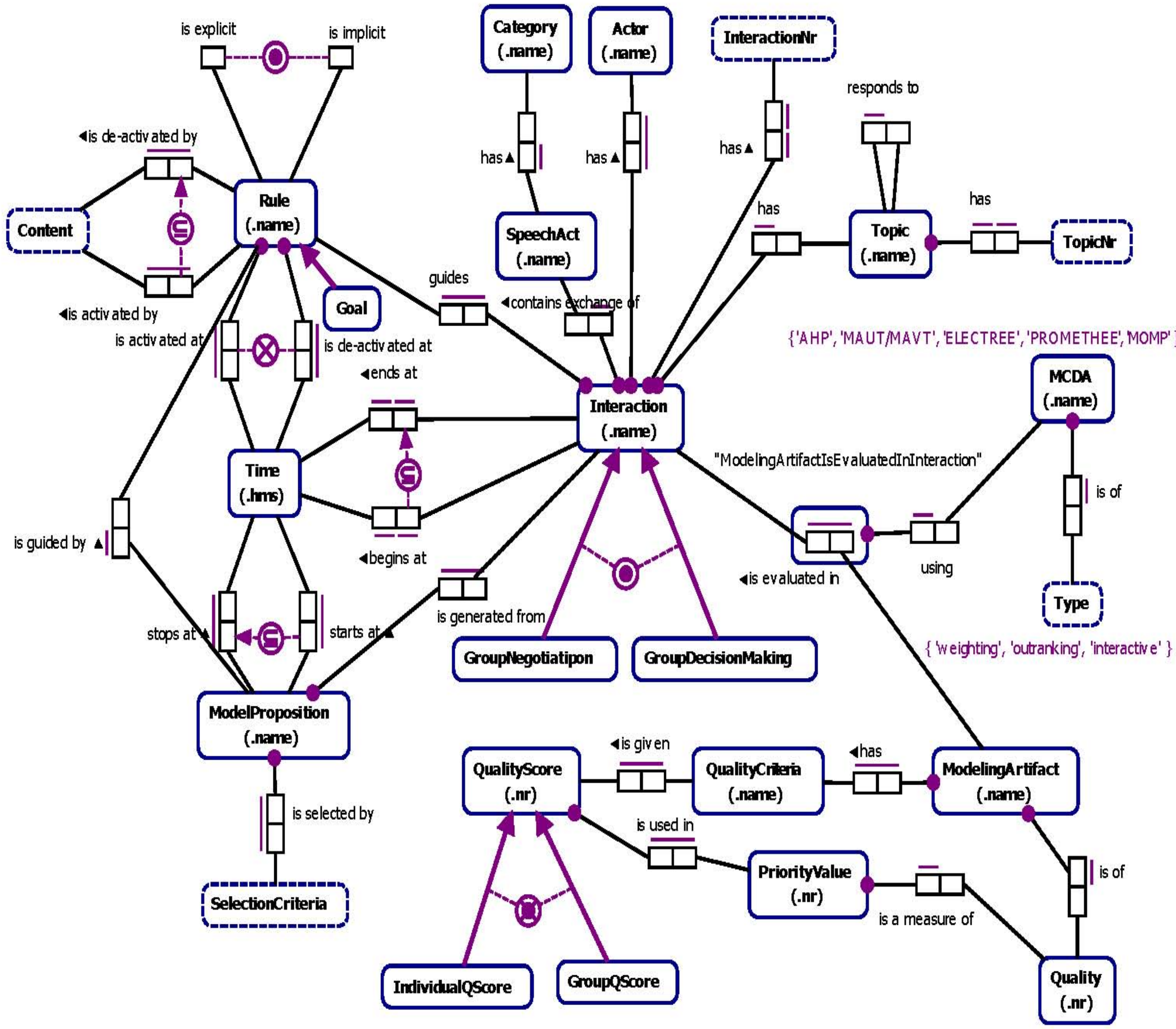


Figure 6. An integrated meta-model for collaborative modeling analysis and evaluation

5 META-MODEL IN USE: ILLUSTRATIVE EXAMPLES

In Sections 2 and 3 we have provided, respectively, frameworks for analysis and evaluation of collaborative modeling processes. To show how these frameworks are linked, we have provided a unifying meta model in Section 4. To demonstrate the theoretical importance and practical significance of the model we provide below some illustrative examples. The examples are drawn from recorded communication/conversations that took place during a modeling session.

5.1 Application of the Meta-Model: The Analysis

Example 1. Interaction analysis in Figure 2 is based on the following excerpt. Table 6 shows the elements of an interaction.

Time	**Actor**	**Speech Act**
02:00	M1	So, where does Ordering start?
02:03	M2	First we have to decide who takes part in it. So we can set that on top of the diagram?
02:10	M1	There are numbers, so that's easy, so probably the purchasing officer is involved?
02:18	M2	Eh ... I guess so.
02:21	M1	So he needs ordering … one second ... "draws 2".
02:26	M2	Erm ... depends on who is the receiving officer.
02:30	M2	Yeah depends on the fact if he is part of the material handler, then the receiving officer is part of ... eh.
02:42	M1	So probably the purchasing officer purchases something ...
02:45	M2	I guess that the receiving officer is the one who is in the company and receives the ...

Example 2. Rule analysis for Figure 3 is based on the following excerpt of modeling session conversations. Extracted elements of a rule from the coded meta-data are given in Table 7.

Time	**Actor**	**Speech Act**
01:25	M1	Let's create 5 swim lane diagrams.
01:30	M2	Yes, isn't that what I just proposed?
08:43	M1	Sequences are started with the START symbol ...
08:45	M2	Yes ....
08:48	M2	Use blocks to indicate activities.
14:06	M1	Use end symbol to mark end of process flow.
14:50	M2	You cannot do decision diamonds in UML activity diagrams.
14:57	M2	You can only have splits and joins of some sort, not the decisions as such.
15:18	M1	So no decision diamonds in UML activity diagrams?
15:19	M2	No; well; maybe.

Some explanation is in order for some of the concepts shown in Table 7 The validation goal is an example of an explicitly stated rule. This is activated at the start of the modeling session and remains so until de-activated at the end of the modeling session. The others are all implicitly stated and are (de-)activated during the interactions as shown by the (de-)activation content**.**

Table 6. Extracted elements of an interaction from the coded meta data

Int. #	Int. Name	Top. #	Top. Name	Speech Act Type/Category	Rsp. to	Time	Actor
1	**INFORMATION SEEKING**	1	**SET CONTENT**	**QUESTION** [Where does ordering start?]		02:00	M1
2	**DECISION MAKING**	2a 2b	**SET CONTENT** **SET GRAMMAR GOAL**	**PROPOSITION** [First we have to decide who takes part in Ordering] **QUESTION** [Can we set who takes part in Ordering on top of the diagram?]		02:03	M2
3	**INQUIRY**	3a 3b	**SET GRAMMAR GOAL** **SET CONTENT**	**PROPOSITION-QUESTION** [There are numbers, so that's easy, so probably the purchasing officer is involved?] **PROPOSITION** [Purchasing Officer is involved in Ordering]	2b 2a	02:10	M1
4	**NEGOTIATION**	4	**SET CONTENT**	**AGEEMENT WITH** [Eh… I guess so]	3b	02:18	M2
5	**DELIBERATIO N**	5	**SET CONTENT**	**DRAWING** [So he needs ordering … one second … "draws **2",i.e.,** number 2 (purchasing officer) on top of first swim lane		02:21	M1
6	**NEGOTIATION**	6	**SET CONTENT**	**ARGUMENT AGAINST** [Erm… depends on who is the receiving officer., i.e., Whether Purchasing Officer belongs to Ordering depends on who is the Receiving Officer]	3b	02:26	M2
7	**NEGOTIATION**	7	**SET CONTENT**	**ARGUMENT AGAINST** [Yeah depends on the fact if he is part of the material handler, then the receiving officer is part of … eh …]	3b	02:30	M2

KEY: *Int.: Interaction* *Top.: Topic* *Rsp.: Response.*

Table 7. Extracted elements of a rule from the coded meta-data

Rule	Int. Name[A]	Content[A]	Time[A]	Int. Name[D]	Content[D]	Time[D]	M.P
VALIDATION GOAL	**DECISION MAKING/ CONSENSUS**	All participants should agree on the model. [Proposed and activated in the Assignment.]	All t	**DECISION MAKING/ CONSENSUS**	De-activated when all or the majority have agreed on the model, i.e. reached consensus.	**End t**	
CREATION GOAL	**PERSUASION**	Let's create 5 swim lane diagrams - [14] **PROPOSITION**	01:25	**PERSUASION**	Yes, isn't that what I just proposed?-[15] **ARGUMENT FOR** 14	01:30	A.C [14]
GRAMMAR RULE	**INFORMATION SEEKING**	Sequences are started with the START symbol …- [148] **CLARIFICATION**	08:43	**INFORMATION SEEKING**	Yes…[149] **AGREEMENT WITH** 148	08:45	A.C [148]
GRAMMAR GOAL	**NEGOTIATION**	Use blocks to indicate activities - [151] **PROPOSITION**	08:48	-	-	-	A.C [151]
GRAMMAR GOAL	**NEGOTIATION**	Use end symbol to mark end of process flow - [225] **PROPOSITION**	14:06	-	-	-	A.C [251]
GRAMMAR GOAL	**PERSUASION**	You cannot do decision diamonds in UML activity diagrams-[245] **ARGUMENT AGAINST**	14:50	**PERSUASION**	You can only have splits and joins of some sort, not the decisions as such-[246] **ARGUMENT FOR** 245	14:57	
GRAMMAR GOAL	**INQUIRY**	So no decision diamonds in UML activity diagrams?[248] **QUESTION**	15:18	**INQUIRY**	No; well; maybe-[249] **ANSWER** 248	15:19	

KEY: *Int.: Interaction* *A.C.: Activation Content* *M.P.: Model Proposition* *[A].: Activated[D].: De-activated*

Example 3. Model proposition analysis in Figure 4 is based on the following excerpt. Extracted elements of a model proposition from the coded meta-data are given in Table 8.

Time	**Actor**	**Speech Act**
14:41	M1	If there is no place, he can't order or there is no availability.
14:45	M2	Yeah, true...
14:50	M2	You cannot do decision diamonds in UML activity diagrams.
14:57	M2	You can only have splits and joins of some sort, not the decisions as such.
16:46	M1	We can also say that if the form isn't filled in well then it is rejected but...
16:55	M2	Yeah ...
17:07	M1	No-route and terminal point from "accept" in swim lane 7, with "no order" ...
17:14	M2	OK..., Yes.

Table 8. Extracted elements of a model proposition from the coded meta-data

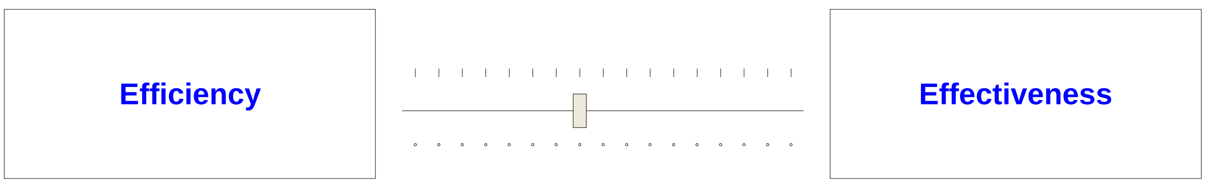
Model Proposition	**Time**		**Rule Name**	**Int. Name**	**Selection Criterion**
	Act.	**De-act.**			
If there is no place, he cannot order or there is no availability. Yeah, true...	14:41	 14:45	**CREATION**	**NEGOTIATION**	Explicitly agreed with.
You cannot do decision diamonds in UML activity diagrams. You can only have splits and joins of some sort, not the decisions as such.	14:50 14:57	- -	**GRAMMAR**	**PERSUASION**	Not explicitly disagreed with.
We can also say that if the form isn't filled in well then it is rejected but... Yeah ...	16:46	 16:55	**CREATION**	**NEGOTIATION**	Explicitly agreed with.
No-route and terminal point from "accept" in swim lane 7, with "no order" ... OK..., Yes	17:07	 17:14	**GRAMMAR**	**NEGOTIATION**	Explicitly agreed with.

KEY: *Act.: Activated* *De-act.: De-activated* *Int.: Interaction*

5.2 Application of the Meta-Model: The Evaluation

Example 4. Evaluation analysis in Figure 5 is based on an evaluation instrument part of which is shown in Figure 7. This instrument is used, first by individual modelers, and then second by a team of modelers, to evaluate the modeling artifact (modeling language, modeling procedure, modeling products-the models and the support tool). The instrument shows, for example, how a modeling procedure is evaluated (using its selected quality criteria). These are assigned scores using the fundamental scale (Saaty, 1980), see also Ssebuggwawo et al. (2009). Upon reaching consensus through negotiation and decision making processes, modelers use these scores in the computation of priorities and the overall quality for the modeling artifacts as shown in Table 9.

Numerical Assessment



Compare the relative importance with respect to: Modeling Procedure

	Efficiency	Effectivene	Satisfactior	Commitmer
Efficiency		2.0	6.0	3.0
Effectiveness			5.0	6.0
Satisfaction				1.0
Commitment & Shared Understanding	Incon: 0.07			

Figure 7. Evaluating a modeling artifact in collaborative modeling

Table 9. Elements of a modeling artifact

Modeling Artifact	Quality		Priority value	Overall Quality	MCDA		Int. Name	Rule
	Criterion	Score			Name	Type		
Modeling Language	Understandability - Clarity ***- Syntax Correctness*** - Conceptual Minimalism	**3** **5** **1** **1**	0.178 0.607 0.096 0.119	0.469	**AHP**	**Weighting**	**NEGOTIATION/ DECISION MAKING**	GRAMMAR RULE
Modeling Procedure	- Efficiency - Effectiveness ***- Satisfaction*** - Commitment & Shared Understanding	**6** **5** **1** **1**	0.464 0.368 0.077 0.092	0.359	**AHP**	**Weighting**	**NEGOTIATION/ DECISION MAKING**	VALIDATION GOALS/ CREATION GOALS
Modeling Product	***- Product Quality*** - Understandability - Modifiability & Maintainability -Satisfaction	**1** **9** **5** **1**	0.064 0.559 0.318 0.061	0.093	**AHP**	**Weighting**	**NEGOTIATION/ DECISION MAKING**	GRAMMAR RULE/ CREATION GOALS
Support-tool (Medium)	- Functionality - Usability - Satisfaction & Enjoyment ***- Collaboration & Communication Satisfaction***	**5** **4** **2** **1**	0.309 0.505 0.109 0.077	0.097	**AHP**	**Weighting**	**NEGOTIATION/ DECISION MAKING**	USAGE GOALS/ CREATION GOALS

6 CONCLUSION AND FUTURE RESEARCH

In this paper, we have developed an analysis framework, the RIM framework, to explore what goes on during the collaborating process. An evaluation framework using an MCDA approach was also developed to determine the quality of the modeling process.

The contribution of the paper is thus twofold. First, it shows how the collaborative modeling process can be analyzed through the RIM framework and how it can be evaluated through the MCDA evaluation framework. Second, it develops a meta-model which unifies the analysis framework and the evaluation framework. To test the soundness of the meta-model, we provided illustrative examples from real modeling sessions. Though simple in description, these examples bring out well the concepts discussed for the meta-model. This implies that the meta-model can as well be applied to a more complex collaborative modeling problem. One key observation is that the types or names of the identified interactions are similar to those identified by Walton and Krabbe (1995) (see also (Reed & Norman, 2004)) in "Argumentation Theory", with the exception of the "eristic" dialogue. This observation is not surprising since in collaborative modeling, participants engage in different types of dialogues before reaching consensus mainly through negotiation and decision making. For future research, we intend to apply the meta-model to modeling sessions, especially empirical tests with experts in industry to further test the theoretical significance and practical relevance and importance of the meta-model. We hope this approach will bring out other salient features that need to be analyzed if we are to effectively and efficiently analyze, understand and fully support collaborative modeling with a GSS tool that combines the analysis and the evaluation.

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