An Extension Proposition for the Agent-Based Language Modeling Ontology for the Representation of Supply Chain Integrated Business Processes

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Abstract: The recent introduction of supply chain systems has redefined the way organizations perceive collaboration. Although characterized as a human driven process by which people communicate, share knowledge, and cooperate internally; collaboration also extends outside the organization and across the supply chain by interacting with both suppliers and customers. While human driven collaboration is fundamental in operating certain business processes, they are usually depicted in models such as high-level abstracts or implicitly integrated in exception related mechanisms. This creates the need for an ontology capable of representing human-driven collaboration. The Agent Lab Language (TALL) ontology was selected as a possible solution to the research problem given its emphasis on agent/ business collaborations. A Bunge-Wand-Weber ontological representation analysis was further used to evaluate the ontological completeness of the Agent Language Lab (TALL). From this analysis, a set of propositions were elaborated in accordance with human-driven collaboration requirements. Following these propositions and the results of the analysis, additional constructs were proposed to the TALL ontology as a solution to the research problem.

Key-Words: Ontologies, Business Models, Business Process Modeling, Supply Chain Modeling, TALL, The agent language lab

1 Introduction

B2B integration is a fundamental collaboration requirement in today’s supply chain. Information, money and goods are exchanged between partners, using integrated processes that enable seamless and real-time interactions B2B interactions and communication [1]. However, lack of system integration between supply chain partners increase the risks of disruptions in the supply chain[2]. Supply chain risk management has been highlighted as a critical component when designing supply chain systems[3][4][5][6]. This research emphasizes modelling supply chain business processes. The notation for social collaboration in supply chains was also the element of investigation. Although the selection of a specific notation depends on many variables, its ability to represent completely and clearly the domain should first be considered. Collaboration can be either informal or highly structured with well-defined protocols between partners. Social business processes introduce new challenges by requiring more flexibility, more agility, and an extended participation of direct and indirect stakeholders. The business process modeling notation should thus be able to reflect the continuum of collaboration forms. The ability of modeling notation to depict less structured, less defined or emerging business processes in the supply chain incarnated in collaborative supply chain software such as e-procurement have not been evaluated. The modeling of collaboration is important when designing supply chain systems as the lack of integration of these systems with enterprise systems has been highlighted as a cause of disruptions of the supply chains by several studies[2][7]. The evaluation of the modeling notation representative ability thus appeared to constitute a first step in the selection and evaluation of a particular business process supply chain modeling notation to model this extended scope of collaboration. Organizations require to quickly and seamlessly adapt to changes and thus to adapt and adopt their business processes. In the meantime, business processes capture through models and their implementation through the information system should still allow for reactivity and innovation. Traditionally many practices, informal knowledge sharing and ad-hoc cooperation participate to business processes but are not modeled nor documented in process maps.

For this research, the Agent Lab Language (TALL) was selected due to its focus on agents and their interactions. This facilitates the modelling of supply chain collaborations (SCC). The approach consists of evaluating the ability of the agent-based language modeling to represent completely and clearly SCC. To perform such an evaluation the Bunge-Wand-Weber Ontology was used to perform a representational analysis. Following this analysis, and the discovery of deficiencies, further propositions were elaborated in order to obtain a more complete set of constructs based on the human-driven collaboration domain. These propositions were further implemented in an adaptation and extension of an agent-based language modeling using the Unified Modeling Language class and state diagram constructs. Finally, an example process was partially modelled in order to evaluate the improvement brought by the extension proposed.

2 Literature Review

Supply chain systems puts an emphasis on the need for an evolutive platform which can support collaboration, not only by enhancing user experience and communities interaction but also in providing the tools and data required in a flexible and efficient manner. Collaboration and participation of emergent communities can then produce tangible or intangible artifacts, including digital content or knowledge in the form of solution to problems, decisions or new innovation proposals. The result of these collaborating communities of individuals is the manifestation of a collective and collaborative intelligence. “Enterprise 2.0” introduced by [8], describes these paradigms in the context of an enterprise. The concept describes the value of collaboration and participation among employees, partners and customers, across departments, hierarchies or any other vertical or horizontal structures. Enterprise 2.0 represents the establishment of flat, network-oriented, collaborative, trustful and transparent culture.

From this overview of new trends in business process management, the criticisms formulated toward models, such as the gap between model and reality, the need to further investigate how collaboration is represented in business process was identified.

Supply chain systems offer a set of tools to support and promote coordination. Their use in the context of organizations, and in particular their role in the support of business processes execution needs however to be integrated to the Business Process Management effort. In order to be able to model technology mediated collaboration involving individuals taken separately or as a group, including social software, as part of the business processes model, a topography of collaboration and its manifestation was built from the available literature.

Collaboration comes from the latin verb “laborare” and the prefix “com-”. The latin verb “laborare” is not only an equivalent for “to work” but also means “to endeavor” and “to produce” and also has the “effort” connotation. Therefore collaboration represent a collective work, conducted with awareness and coordination of the participant to produce an artifact, the concrete representation of the collaboration goal. In the context of information technology, the artifact produced is the result of human conception mediated by technology. In accordance with the definition given by [9], the activities executed to produce the artifact indicates that a collective and common goal is supporting the collaborative effort. Another property of collaboration is its temporal dimension, including its duration and frequency. Ad-hoc collaboration is limited in duration but is repeated over and over. On the contrary, a feasibility study might require a longer collaboration and might be frequent in engineering companies.

According to the definition, awareness and coordination play a central role in collaboration. Fuks et al. [10] add that communication, coordination and cooperation form the core elements of collaboration and that awareness mediates and is fostered by these 3Cs. Cooperation is defined as work occurring in a shared space, in opposition to a private space used for independent work. The concept of shared work space refers to the collective access, and use of the resources required to produce the tangible or intangible artifacts representing the achievement of the shared goal and its subjacent shared objectives. Awareness is defined by the participants’ conscience resulting from the feedback on their actions and exchanges and their impact toward the objectives defined to reach the goal. Communication is the underlying mechanism allowing coordination and awareness. Coordination can be defined as the organization of activities in a flexible and effective way to achieve the collaboration goal or its subjacent objectives.

Furthermore, awareness is possible through communication and increases with memory. The collaborative memory represents the accumulation of formal and informal information exchange [11], the set of participants actions, and their resulting transformation on the collaboration artifact. Collaborative memory further represents a particular instance of the collaborative knowledge built across collaboration sessions.

The method used with collaboration maturity model includes an analysis of business process models and defines new models reflecting the collaboration maturity level targeted. Although models are not the only resource used to assess and build the current and targeted collaboration maturity level, the issue of the representativeness of the models, and in particular its relations with the notation ability to completely and clearly describe collaboration is also impacting the maturity level evaluation. From the analysis of current models to the modeling of collaboration according to the targeted level of maturity, the notation should be able to unambiguously and completely represent collaboration.

Collaboration activities are structured by the mechanisms described above, but smallest unit of collaboration is the activity. Engestrom [12] proposed the following approach as part of the activity theory (figure 1) :

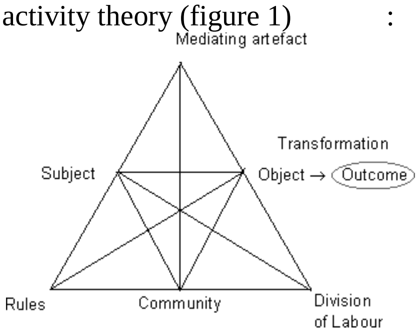

Figure 1 The Structure of Human Activity

In Figure 1, a subject represents the agent performing an activity, an object is the subject activity purpose represented. A subject performs an activity through the mediation of tools (mediating artefact) to produce a result (outcome). The activity is performed in a social context (community) which structures roles and responsibilities (division of labour). Roles and activities are bound by social, cultural, or organizational rules for instance.

In addition, activity has a hierarchical structure composed of actions and operations. As Constantine [13] explained, actions are taken to achieve goals and further translated into operations which are bound by conditions. The purpose of an activity can be depicted as subjacent goals expressed in actions and further in conditions adapted objectives. Following these clarifications on collaboration and human activity, a review of the current proposed modeling approaches was performed.

Boeve et al. [14] proposed a new approach to modeling collaborative task as one activity in the process but with an extended context. The task context is composed of the goal of the task, a defined set of participants, a due date, the available resources, the information and the knowledge required to perform the task, the collaboration channel(s), the activity history, and the dependencies with other tasks in the process. However no formal specification of the notation was found. Morisse, Drews and Schafer [15] proposed an extension to the Business Process Model and Notation 2.0 (BPMN 2.0) in order to model coordination and collaboration in processes of the Business-IT Management (BIM). They added domain specific tasks to model cooperation, both formal and informal, decision-making, expert consultation, publication of results and conflicts. Brambilla, Fraternali and Vaca [16] also proposed an extension to BPMN 2.0, in order to model social participation in business processes. They distinguish between three types of actors, including performers and observers who are part of the organization or external and who can directly or indirectly participate in activities. A community sub process denotes an ad-hoc process, several social network related tasks are added as well as events to model activities that could include social network communities. Koschmider, Oberweis and Zhang [17] model for coordination of collaboration in social networks is based on the Petri Nets notation. A community process (CP) is defined as sequences of activities performed by social network members in order to produce a collaboration output. CP is composed of single and collaborative activities, or sub processes including these activities, as well as resources in the form of Community process Objects (CPO). The CPO are further subdivided into flowing objects which are transferrable between activities and non-flowing objects which are not transferrable such as the resources executing the activity. As an example a Community User (CU) is a non-flowing object while a Community Content (CC) is a flowing object. First, it is to be observed that all these contributions depict collaboration with different business process notations. Would this mean that notation is not equal in their abilities to depict collaboration? Secondly, the collaboration described across the contributions does not explicitly refer to a common collaboration reference model. Collaboration exists for a long time, and has been studied by various scientific fields, including biology, social science and information technology, but to our knowledge no widely accepted collaboration reference model is available. Only recent contributions were collected because the assumption was made that knowledge being cumulative and later research being built on previous ones, a common reference model should have been referenced across the contributions.

2.1 BWW Ontology

The BWW Ontology representational analysis evaluates some properties of the expressive quality of a grammar, through its ability to represent and describe the world. The use of ontologies has been acknowledged as a powerful tool in the representation of Business Information Systems requirements [18]. The BWW framework is based on an adaptation of the ontology elaborated by Bunge [19]. In philosophy, ontology is the branch of metaphysics which studies what exists, including the relations that may exist between objects, their categorization, their structure, their properties, their similarities, their states or their changes. Wand and Weber [20] used the ontology as a tool, the representation model to analyze modeling constructs. The BWW ontology is assumed to be a clear and complete representation of the constructs required to describe the world and its phenomenon as captured by an information system model.. Although other ontologies exists, and other quality frameworks [21] could have been used in order to evaluate business process modeling grammars, the BWW Ontology was chosen for the following reasons:

a) The BWW Model has been developed with Information System modeling in mind. It is well-formalized and represents domain independent but information system related concepts [21] [22].

b) The methodology was chosen due to a rather long history of representational analysis applied to modeling grammars, such as Entity-Relationship [22], and UML [23], notations for instance.

c) The well-defined process defined for conducting a representational analysis [24].

The BWW ontology allows evaluating the representational capability of a specific grammar through an evaluation of its ontological clarity and completeness. If a given modeling grammar is ontologically complete and clear, it should then offer a complete representation of the things, the phenomenon and their relations in the world. Such a modeling grammar would then be the best candidate to model a specific domain. The evaluation is based on a reference meta-model, which is a priori independent of domain specific constructs. A representational analysis of a modeling grammar consists of mappings that allow for discovery of ontological deficiencies. The mapping between those two (representation model and modeling grammar) is executed in a bi-directional way: the grammar constructs are mapped to the representation model and vice versa. This allows for the evaluation completeness (or incompleteness when there are deficiencies) and clarity (or overloading, excess and redundancy) [25].

As illustrated in figure 2, the mapping from the BWW ontology constructs (represented by the set of squares) to the evaluated grammar constructs (represented by a set of circles) is called the "representation mapping". Two kinds of ontological deficiencies can then arise following this transformation: the BWW ontology constructs map to more than one element or to no element in the evaluated language. In the first case, the ontological deficiency is called redundancy (represented in red). When redundancy occurs, this means that the evaluated grammar represent the same ontological construct more than once. This might in turn become a source of confusion for the modeler who will be presented with two constructs to model one ontological construct. In the second case, the absence of corresponding construct in the evaluated grammar is called a deficit. When a deficit occurs, this means that the evaluated grammar has no construct to represent the ontology construct and thus might incompletely represent the world and its phenomenon. No deficiency means that there is exactly one corresponding construct in the evaluated grammar for each of the BWW ontology construct. If no ontological deficiency can be found, then the evaluated grammar might have all the required constructs to model the world and its phenomenon. The grammar is said to be ontologically complete. However, clarity does not only depend on the absence of redundancy. The second part of the representational analysis maps the constructs from the evaluated grammar to the BWW ontology constructs and is called "interpretation mapping" (refer to figure 2). Again two kinds of ontological deficiencies can arise: overload (represented in black) and excess (represented in blue). An overload of the evaluated grammar constructs means that one construct maps to more than one BWW ontology's constructs. In such case, the overloaded construct usage can become complex and depend on its context for instance. This would in turn reduce the clarity of the grammar and make its model prone to multiple interpretations. An excess represents the absence of a corresponding construct in the BWW ontology. A construct might thus be in excess and exist only to answer the evaluated grammar formalism or internal requirements, without any ontological representation capability. To sum up, overload, redundancy and excess deficiencies will affect the ontological clarity of the language, while a deficit deficiency will affect the ontological completeness of the language. Clarity and completeness in turn constitute the ontological representativeness of the language [26]. The representation analysis of a modeling grammar can thus be used to evaluate if a given grammar has all the required constructs to completely and clearly model the world and its phenomenon or a specific domain. The evaluation objective is then twofold, first to be aware of the grammar limitation, and second to be able to either deal with these limitations when using the grammar or design additional elements (by extension) or new constructs in order to overcome the grammar deficiencies.

In order to perform the representation and interpretation mapping, a mix of visual and textual analysis of the BWW ontology must be performed. Following the recommendations of Rosemann, Green and Indulska [27] the meta-models of the BWW ontology and the evaluated notation must and were built using the same modeling language. The BWW meta-model elaborated following Davies et al. [28], and using the Entity-Relationship (ER) modeling language was thus transformed to an equivalent model in UML. The UML representation of the BWW Ontology meta-model presented in figure 2 is also an adaptation of the UML meta-model presented by Kiwelekar and Joshi [29].

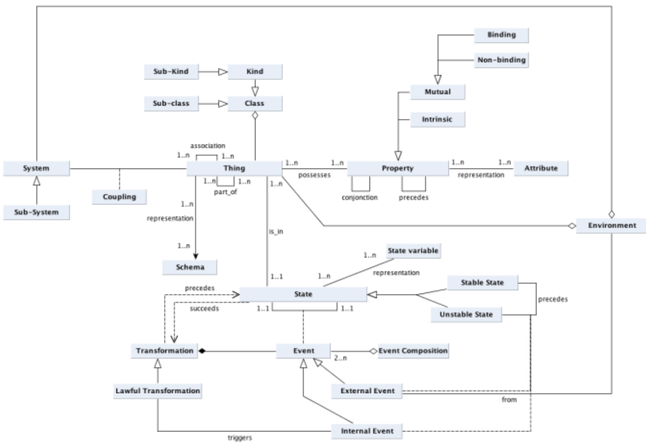

Figure 2 BWW Ontology UML Diagram

Although the meta-model of the BWW Ontology helped in understanding the ontology, the comparison with an evaluated grammar was not straight-forward. The issue resided mostly in the absence of a language independent way to describe an evaluated grammar constructs graphical notation and relations as well as their meaning. In the BWW ontology there is no additional graphical layer, while the evaluated grammars are first graphical notation. The illustrated ER and UML meta-model helped to identify the ontology clusters, the group of related constructs and their relations with other groups.

The identified clusters are:

a) The Thing cluster including properties, attributes, schema, class and kind.

b) The Transformation cluster, including lawful transformation, but also “acts on” and coupling.

c) The Event cluster, including internal and external event, event composition, conceivable event space, lawful event space, well-defined and poorly-defined event.

d) The State cluster, including stable and unstable state, conceivable state space, state law, lawful state space.

e) The System cluster, including system environment, system structure, system composition and decomposition, level structure.

Due to the semantic distance between the BWW ontology on one side, the reference meta-model language used (ER and UML) and the reference model on the other side, the analysis was conducted with the help of both the reference models and the reference textual descriptions.

2.2 The agent lab language (TALL)

An information systems diagram offers a highly abstracted view of process-wide behaviors through a tree structure representation of the interactions, their composition and the roles involved. Interactions are related to each other by dependency ('is part of' relation) or decomposition ('precedes' relation) [30]. Each interaction is defined at a specific level in the tree. Agents perform their behavior when an interaction is represented as a leaf. The completion of interactions follows the tree structure, a bottom-up approach from leaf to parent: a parent interaction is completed when all its children are completed. The TALL ontology is described in detail in table 1

The TALL language was chosen for this research because it is focusing on agent behaviors and interactions in business processes. For instance, employees interact with the company's partners or with other company's employee; employees also interact with each other in order to execute processes that are part of the supply chain management. These interactions can follow a protocol, either pre-agreed upon in the case of a partnership, or dependent on a social context in the case of human informal and formal interactions.

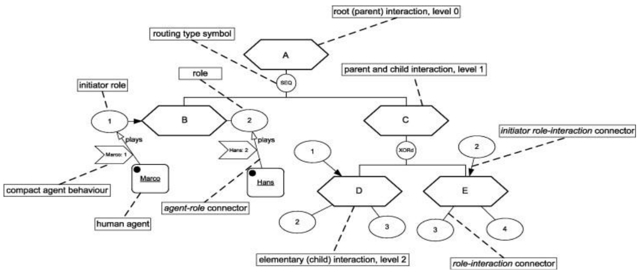

Figure 3 Interaction Structure Diagram Elements

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Table 1: Interaction Structure Diagram Elements

Symbol	Semantic
Interaction	An interaction
Role	A role
Agent	An agent
Compact Agent Behavior	A compact agent behavior
Route	A route
	A role-interaction association
	An Initiator-role for a role-interaction connector.
	An agent-role association
	A interactions tree
Human	A human agent
Software	A software agent
Synthetic	A synthetic agent
	A human-software association

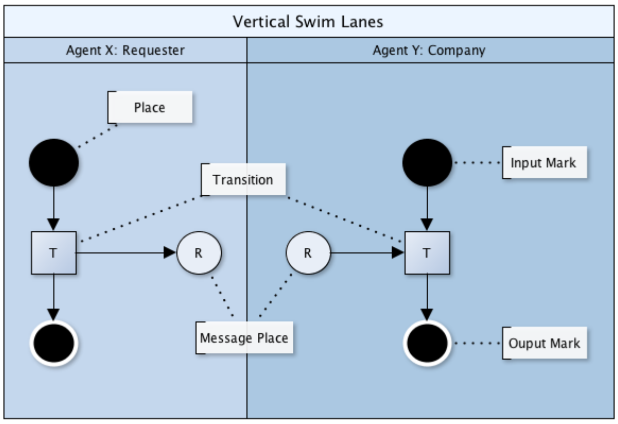
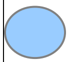
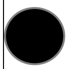
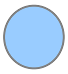
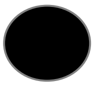
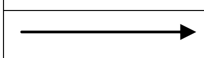


Figure 4 Agent Structure Example

An Agent Behavior diagram (figure 4) represents a local view of a behavior in an interaction from the owner's agent perspective. Note that in the diagram illustrated above, if the behavior is described from Agent X theRequester, then the Transition of Agent Y theCompany are expected. Some references of the TALL language have thus used a cloud symbol to depict this expected behavior, an interaction belief as described by Stuit and Szirbik [31]. On the other hand, the intended behavior, which in the case is described in figure 4, is the behavior of the Agent X theRequester, might also represent a planned, a currently executing or the trace of a behavior. The agent behavior diagram elements are described in detail in table 2.

Table 2: Agent Behavior Diagram Elements

Symbol	Meaning
	A swimlane, this represents an agent an include its intended behavior for a given interaction. An agent may have several behaviors associated with a given role in an

	interaction.
	A transition: intended transition and expected transition. This represents an activity occurring in the agent's behavior described.
	A place, this represents a state in the agent's behavior de-scribed.
	An input place, this marks the beginning of a behavior net.
	An output place, this marks the end of a behavior net.
	A message place, this allows tokens to flow from one behavior to another in an interaction. A message place represents the transfer of a token and another message place represents its reception.
	A token, this represents a mark of the internal state of a behav-ior.
	An Arc: incoming arc and outgoing arc. An incoming arc is a guard function which must evaluate to true for the arc to pass on the token. The function is a more generic weight property associated with an arc.

3 Research Method

In order to justify the use of the Agent Language Lab (TALL) ontology and identify constructs required for its extension, the TALL ontology was compared with different grammars used in information systems including UML, BPMN and PetriNet. The grammar constructs were then identified, enumerated and their representation described following the specifications given.

A comparison of the completeness quality of the grammars (BPMN, UML, Petrinet) was thus performed with the help of the previous work of Recker and Indulska [32] and Koschmider et. al[33] for PetriNet , Morisse, Drews and Schaffer [34] as well as Brambilla, Fraternali and Vaca [16] for BPMN and Valverde [23] for UML by using an ontological evaluation analysis.

The ontological evaluation analysis will be done using the Bunge-Wand-Weber model (BWW-model). The BWW model is an ontological theory initially developed by Bunge [19] and adapted and extended by Wand and Weber [20]. The use of the BWW-model is justified on two grounds. First, the model is well founded on mathematical concepts. Second, prior research on the evaluation of grammars shows that the BWW model has been used successfully in information systems research [27][25].

The ontological results of the previous grammars were then compared with an ontological BWW analysis performed on the TALL ontology. As a result of the analysis and in order to obtain the most expressive grammar to model collaboration and following the maximum ontological completeness theory[35], a third language had been identified and investigated in order to obtain a more complete representational ability by eventually combining constructs of two or more grammars.

In order to evaluate the pertinence and applicability of the proposed TALL extended ontology, a collaborative supply chain process was partially modelled in order to demonstrate its use for the modeling of supply chain systems.

4 Results and findings

A representational analysis of the TALL language was thus conducted, and began with the collection, enumeration and classification of the diagrams and constructs of the notation as exposed across the TALL research papers. Tables 3 and 4 reveal the BWW ontological evaluation results for the TALL ontology.

Table 3: TALL Representation Mapping

BWW constructs	TALL constructs	Description
Thing	Agent can represent physical active or passive thing. A swimlane represents an instance of an agent. A synthetic agent can represent a composite thing.	An agent can represent a concrete thing either passive (a software agent can represent a passive thing) or active.
Property	Agent type, name, swimlane instance name and role.	An agent name and type are properties in general, and its instance name, in the case of a swimlane in an Agent Behavior diagram, is a property in particular. It is mentioned that a role adds properties to an agent and thus can represent a binding property.
Class	Agent	An agent can represent a class of agents possessing a common property. For instance software or human agent.
Kind	Agent	An agent can represent a kind as it can be an agent group. An agent group contains agents with more than one common properties.
State	Input place, Output place, Place and token	Input place represents the initial state of a behavior. A place represents a state between transitions and at a given instant is marked with a token to represent the behavior state. An output place represents the ending state of a behavior.
Conceivable State	N/A	
Space		
State Law	Place to transition to place	The place transitions to one or more places indicates that only the successive states for which an outgoing arc is available can be lawful.
Lawful State Space	N/A	The capacity of a place is not explicitly depicted in the notation description found.
Stable state	Output place	The output place mark the end state of the behavior and can not be further changed by internal events (transition or message).
Stability condition	The G function associated with an incoming arc.	Although without any graphical symbol, the function is defined as part of the formal definition of Behavior Net. It defines a boolean expression for incoming arcs.
Unstable state	Place, Input Place and Token	As with Petri Net, the input place, place and token depicts states that could be changed upon internal (like transition) or external events (like message).
History	N/A	
Event	Transition, Message Place, Input and Output Place.	Transition represents a bridge between two states while a message place represents an external event that local agent receives. An output place also represent the behavior's termination event.
Conceivable Event Space	N/A	Although the message place has a defined data type, agents interactions through their behavior does not ensure that the agents will send the correct data type in a message. Further pre-interaction, on-the-fly or mediator

		alignment might be required.
Lawful Event Space	N/A	
External Event	Message Place	Within an agent behavior representation a message place depicts an external event.
Internal Event	Transition	A transition can be considered an event because it represents the transition from one state to another.
Well-defined Event	Transition, Output place, Input place	A transition leads to a new state which can be predicted according to the transition outgoing arcs associations. An output place being the end state, the next state is always the end of the behavior.
Poorly-defined Event	Message Place	Upon the reception of a message, the next state of the behavior is hard to define. The message content might not be the expected one and the agent behavior might need alignment.
Transformation	Transition, interaction	As in Petri Net, a transition change the state of the behavior. An interaction being the execution and the result of two or more agent behaviors, the process will change from one state to another.
Lawful transformation	Route [SEQ, PAR, XOR]	The route depicts the lawful organization of interactions, either sequential, parallel or exclusive choice (XOR). Additional decision rules can be specified on the route (SEQd, PARd, and XORd). Although a behavior is agent dependent, an interaction follows a parent-child and routing relation.
Acts on	Arc, Role	A role acts on an interaction by initiating it for instance. An arc depicts a relation between states.
Coupling	Agent association, role-interaction association and agent-role association.	An agent association, such as a software-human agents association depicts the coupling of both agents. A role-interaction association also depicts the influence of a role on an interaction. An agent-role association also depicts the particular influence of an agent instance in a given role.
System	Interaction	An interaction representing the action of behaviors on each other, coupling exist between any two agents engaged in the interaction.
System Composition	Interaction tree	The interaction tree depicts the composition of the business process, especially through the interactions parent-child relations.
System Environment	N/A	
System Structure	N/A	
Subsystem	Interaction tree	An interaction tree represents the parent-child relations of interactions. A child interaction can be considered a subsystem of its parent interaction.
System Decomposition	Interaction tree and swimlane	The interaction tree represents the decomposition of parent interactions into child interactions. A swimlane represent an agent and contains the decomposition of its specific behavior.

Level Structure	Hierarchical tree of interactions and roles	The tree representation of interactions and roles can represent a hierarchical structure of both roles and interactions.
Process	Interaction	An interaction can represent an ordered sequence of behaviors if aligned with a protocol. The protocol defines how behavior should be aligned before an interaction.

Table 3 includes the BWW ontology mapping to TALL constructs. The mapping revealed deficit and redundancy ontological problems highlighted below:

1. Deficit: The BWW constructs Conceivable State Space, Conceivable Event Space, Lawful Event Space, Lawful State Space, History, System environment and system structure have no corresponding constructs in the TALL grammar.

2. Redundancy: The BWW constructs State, and in particular unstable state, Event, Well-defined Event, Coupling, Acts on, System Decomposition and Level Structure are represented by more than one element in the TALL grammar. The BWW Thing and transformation construct is also represented by both agent and swimlane.

Table 4: TALL Interpretation Mapping

TALL Constructs	BWW constructs
1) Interaction	An interaction is composed of at least two agents each exhibiting a behavior to fulfill a role in an exchange and thus depicts a transformation.
2) Role	A binding property of an agent with an interaction.
3) Agent	An Agent can represent thing in the world, even passive thing. Note that an Agent Prototype diagram also appears to model a thing as a physical entity. A synthetic agent can also represent a composite thing because it can not only inherit properties of its parts but have its own properties and behaviors. Agent also represents a class, like human, software or synthetic agent with a single common property. An agent can also represent an Agent group, in which case agents posses more than one common properties and thus can represent a kind.
4) Agent Association	An association between two agents, a human and a software agents for instance, represents coupling between the agents.
5) Compact Agent Behavior	Compact view of a behavior which indicates a reference to an intended or already manifested local behavior. This construct appears to be in excess.
6) Route	A lawful transformation as it indicates which interactions are allowed as part of the parent interaction. Furthermore, route can have additional decision rules.
7)Role-Interaction association	A role affects an interaction, especially in the case of a mediator role played by an agent to allow for an alignment of the behavior . The role-interaction association can thus represent coupling.
8) Initiator Role-Interaction association	Represents a role which initiates an interaction. Initiator depicts an additional property of the role in the interaction.
9) Agent-Role Association	A role affects the behavior of an agent, possibly adding properties to the agent. The association can represent coupling.
10) Interaction Tree	A system with its composition and decomposition and level structure. The interaction tree describes a system through its interactions. The interactions are further decomposed and represented hierarchically with a dependence of the parent on the child interactions.
11) Role tree	Represents in a hierarchical way the relation between roles. It can be mapped to a level structure.
12) Swimlane	Represents a local behavior which is a subsystem of the interaction system.

13) Transition	Represents a transformation, the token can be modified by the transition and lead to a new state of the behavior.
14) Place	In a synthetic agent behavior representation, a place might represent concrete objects. For instance, a virtual community agent modeled as a synthetic agent could have a place representing customers, a place for company's employee.
15) Input Place	Represents an event, the first event that initiate the behavior. It also represents the initial state of the behavior which is unstable because it will change with transitions.
16) Output Place	Represents the ending event of the behavior, a well-defined event because we know what is the state of the behavior beyond this event.
17) Message Place	Is an event which from the receiving behavior point of view represents an external event. This event is also poorly-defined because the following state of the receiving behavior is only expected and represents a belief from the sender's perspective.
18) Token	A token represents the marking of the behavior state. It represents a state, as in the Petri Net notation. The state represented is also unstable as it can change after a transition. Token is apparently assumed to be always equal to one.
19) Arc	Arc comes from the Petri Net notation and thus represents the BWW acts on construct because it depicts a relation between things.

Table 4 includes the TALL ontology mapping to BWW constructs. The table reveals the overload and excess ontological problems below:

1. Overload: An agent maps to several BWW entities, such as Thing, Class and Kind. A transition also maps to more than one BWW entity, including a transformation, and a well-defined internal event. An interaction tree can also be interpreted as a BWW System, System Decomposition, System Composition and Level Structure.

2. Excess: Only the Compact Agent Behavior was found to have no mapping construct in the BWW ontology. From our understanding of the notation, the association of an Agent with a Role in an Interaction Structure Diagram would have been sufficient to indicate the agent's behavior.

In our evaluation of business process modeling notation toward the representation of human-driven collaboration, the complete ability of a notation to represent all the mechanisms involved was the first concern. A comparison of the completeness quality of the grammars (BPMN, UML, Petrinet) was thus performed with the help of the previous work of Recker and Indulska [32] and Koschmider et. al[33] for PetriNet , Morisse, Drews and Schaffer [34] as well as Brambilla, Fraternali and Vaca [16] for BPMN and Valverde [23] for UML.. From the comparison of deficits highlighted in the table 5 the following combination could be deduced and potentially offer an increased completeness.

Table 5 Ontology Evaluations Deficit Comparison

BWW constructs	Petri Net	BPMN	UML	TALL
Thing	●	●	●	Agent
Property		●	●	Agent type, name, role and instance id.
State	●		●	Input State, Output State, and Place and Token
Conceivable State Space			●	
State Law	●		●	Place → Transition → Place
Lawful State Space	●		●	
Event	●	●	●	Transition, input place, output place and message place
Conceivable Event Space			●	
Lawful				

Event Space				
Transformation	●	●	●	Transition, Interaction.
Process	●	●	●	Interactions
Lawful Transformation	●	●	●	Route in interactions and G function on incoming arcs
History			●t	
Acts on	●	●		Arc, Role
Coupling		●	●	Agent, Agent-role, role-interaction association.
System		●	●	Interaction
System Composition		●	●	Interaction tree
System Environment		●	●	
System Structure				Interaction Diagram
Subsystem				Agent Behavior Diagram
System Decomposition		●	●	Interaction tree and swimlane
Level Structure		●	●	Interaction and role hierarchical tree
Stable State			●	Output place
Unstable State	●		●	Input place, input place and token
External Event		●	●	Message Place
Internal Event	●	●	●	Transition
Well Defined Event	●	●	●	Transition, Input place, output place.
Poorly Defined Event		●		Message place
Class	●	●	●	Agent (type)
Kind		●	●	Agent (group)

Petri-Net with UML would result in only four missing constructs: Lawful Event Space, System Structure, Subsystem, and Poorly-defined Event. On the other hand, BPMN with UML would result in three deficit Lawful Event Space, System structure, subsystem. Finally, TALL with UML would allow for only one deficit, the Lawful Event Space.

According to the representation analysis performed, the best combination to obtain a more complete language would be TALL and UML. However, it is to be noted that BPMN and UML were associated in previous works, and Petri Net with UML exhibits more defi-ciency but without taking into account the Petri-Net variants. Furthermore, choosing TALL with UML class and state diagram for instance could potentially bring some confusion when modeling a Petri Net-based local intended behavior in TALL and a State Machine diagram in UML. This is due to the visual proximity of the constructs in both notations.

The UML grammar was selected as a grammar that could be used to complement the TALL ontology in order to compensate for ontological deficiencies. The UML grammar is strong ontologically speaking, although there are several BWW constructs that cannot find representation in any diagrams: system structure, subsystem, lawful event space, acts on, poorly defined event [36].

The first proposition is to model the artifact (passive thing) and the agent (active thing) separately. This way, an artifact representing the goal and tangible outcome of the collaboration can also be shared among agents. In addition, a shared artifact is constrained by rules. Agent behaviors on the other hand could also follow rules, but more in the form of policies. Moreover, a shared artifact can be composed of other shared artifacts, allowing the representation of a composite artifact. An artifact structure can thus be represented in order to model the relations existing between the whole and its parts. In order to express the required rules that could apply to an artifact, the UML state machine constructs can be used, thus depicting the conceivable state and event space with the additional representation of the rules applying before the transition to another state. For instance, a rule reference could be applied on a transition. In the upper part of such a diagram, the properties of the artifact, related to the applicable rules could be enumerated. An artifact can then be associated with an objective, or a child interaction.

The second proposition is to model the context of an interaction. This context should contain the history of the artifact associated, but also past interactions associated with this particular objective. Because agent can build knowledge from memory, the memory mechanism described in collaboration can be shared by agents through the context. Moreover, a context should be shareable between interactions and interactions instances. A synchronization and marking of context in parallel interactions could also allow depicting the agent alignment.

The required auditing of processes and capture of interactions, actions on or toward the realization of the artifact should be available across the whole process. Although most workflow management systems have log features, the context proposed should explicitly represent the audit of the current artifact and interaction.

This leads to a distinction between the current workspace and the context, the workspace represents the shared goal artifact and shared objective artifacts as they are transformed or realized by agent's interactions. The shared artifacts organization in the workspace can be represented by a UML class diagram representing shared artifact relations.

In order to evaluate the pertinence and applicability of the propositions, a collaborative supply chain process was partially modeled. The collaborative process described here is an e-procurement content localization quotation process.

The quotation process can be rather complex and is usually determining not only the cost of the project, but also the specific sequence of steps that will be used for this particular project and which could potentially benefit to all other (con-)current and future projects.

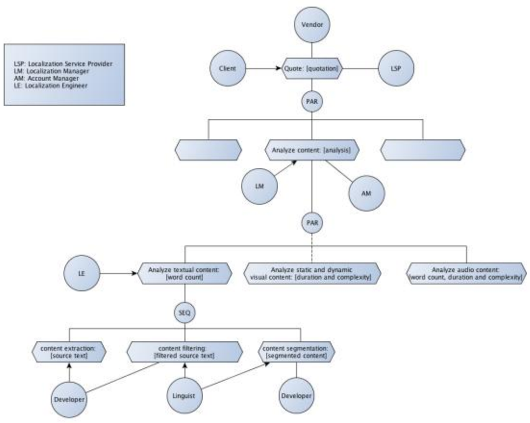


Figure 5: Overall Partial View

This process involves three categories of stakeholders: the requesting organization and its partners, commonly grouped into a client role, the organization in charge for the quotation, denominated the localization service provider (LSP), and the vendor role which group both linguistic, engineering, and domain experts.

The main goal of the process is to provide an accurate estimation of the cost and duration of the project, with all the technical and human resource unknowns possibly identified, evaluated and planned. At a high level, the process can be described in the following terms: the source content (provided by the client in the original locale) is received and analyzed with the help of localization tools to produce a quantitative analysis (word count). According to the price negotiated with the vendors, and an estimation of the duration according to work average, a priced quotation is delivered specifying the estimated duration of the localization work requested. However, in practice, during this process much expertise is usually required, technical issues usually appear and a specific knowledge of the content and its context is usually built. This might be due to the complexity of the content, which can include textual, visual or audio elements to be localized. The source content can also appear in different context, for instance in the course management application, or the course activity framework or the course content itself. Here the potential interactions are depicted with a dashed line. The roles are mostly generic but from the following interaction diagram, different type of agents possibly involved can be identified.

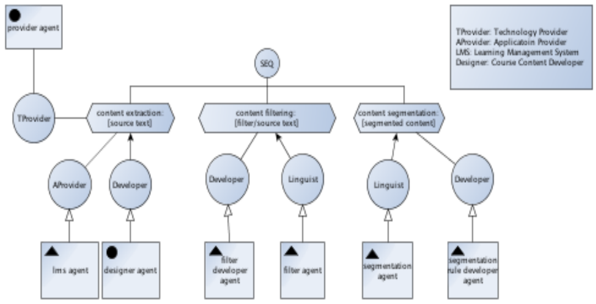


Figure 6: Agent in Interaction

The further roles identified in the interactions and the agents fulfilling these roles can be depicted as illustrated in figure 6. The developer role can represent for instance the role of the content developer in the extraction of content, or the role of the content filter developer in the filtering interaction, or the role of the segmentation rules developer in the segmentation interaction.

In order to be able to only localize relevant content, the content must be filtered out of comments or variables. Then, a set of segmentation rules, inherited from the natural source language, and the addition made by the content designer must be specified to obtain coherent units of content with a high potential of repetition and thus reusability through the Translation Memory (TM). For instance a filtered unit of text, such as an instruction might contain more than one sentence and additional variable which must be properly segmented as a whole to be reusable across courses.

Although the agents fulfilling the linguist and developer roles are usually depicted by individual, in practice, the linguist and developer are interacting with a service, such as the filtering or segmentation service. Furthermore, not only one linguist or developers work on a specific filter. A community of developers might for instance work on some specific application filter. Because content must also be indexed and available to search through keywords, the developer community of content indexer are also providing help in the filtering and segmenting sub processes.

The possible composition of the synthetic agent filter developer agent is represented in Figure 7. The Filter Integrator is a developer in charge of the filter engine. The filter Engine represents the manifestation of the filter when applied to the content. The Community filter Developer represents a community of developer working on creating and improving digital content extraction filter. This community represents an individual developer providing contributions on a converter application on a community question and answer website, or a developer contributing to a converter piece of code in a public repository.

An artifact diagram can help to represent the relation existing between the goal artifact and the specific objective artifacts. In the diagram depicted in figures 5 and 6, the artifact produced following the interaction is represented in between brackets. For instance, “content filtering:[filtered source text]” means that the interaction's goal is to filter the content and this goal tangible artifact is the filtered source text form. The figure 8 depicts with a simplified UML class diagram the relations between the artifacts.

A specific artifact can be modeled as in figure5, including its properties and states, as well as rules governing state transitions. This view allows representing the conceivable and lawful states for a given instance of the Scope type resulting from the interactions shown in figure 6.

The context construct is shown as a round rectangle with dashed line in the following intended behaviors between a community filter developer, a filter integrator and a linguist. As shown in Figure 10, a context can be shared and does not have to be unique. For instance the shared context between the filter integrator and the community filter developer is the need to filter text content (or audio, or video) from the content provided. This context is including past, present and future dimension because the filter might have been built in the past, the search might be current and the usage and customization might happen in the future. Note that the behaviors represented are only intended from the filter integrator point of view and further alignments might occur during execution. The shared artifacts filter and source content are also represented in the interactions workspace, symbolized by the frame including swimlanes.

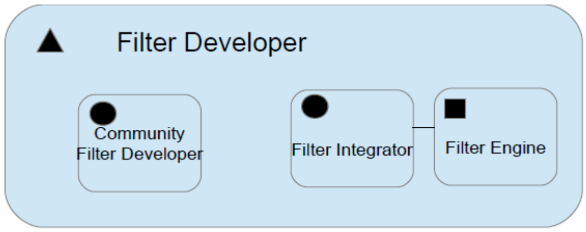


Figure 7: Filter Developer Agent

Following the partial modeling of this particular quotation process, the following conclusions can be drawn. First, human-driven collaboration and the interactions it generates are governed and executed towards the achievement of particular objectives which participate to the achievement of a more general goal. The individual objectives might not be all known prior to the collaboration execution and might change or further objectives defined in response to internal and external event which affect the state and thus the progress of collaboration toward its goal. Secondly, the monitoring of the collaboration shared artifacts relations and status appeared of prime importance in the collective awareness of the progress of collaboration, as well as in the collective definition, evaluation and realization of intermediate objective. Thirdly, the collaborative and collective memory is playing an important role in the adaptation of the individual objectives and resulting interactions to a particular context in order to achieve the collaboration goal. These observations are however partially represented in human-driven collaboration models, and partially due to the ontological deficit observed following the representational analysis. Although processes are represented as a sequence developing in a temporal dimension toward a future, it appeared that a new dimension, transversal to the development of the activities can be added. This dimension not only represent past experience and practice accumulation, but also the current and concurrent context of a particular activity in the sequence.

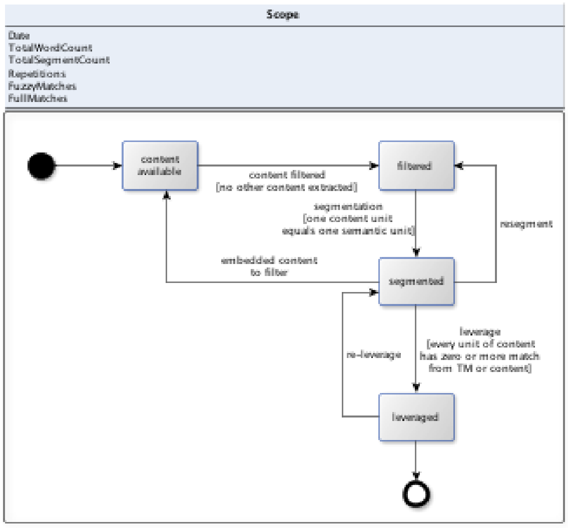


Figure 8: Artifact Type diagram

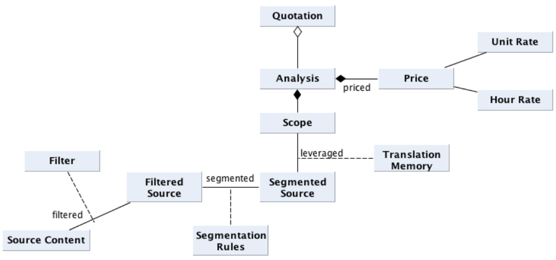


Figure 9: Artifact Relations in a shared workspace

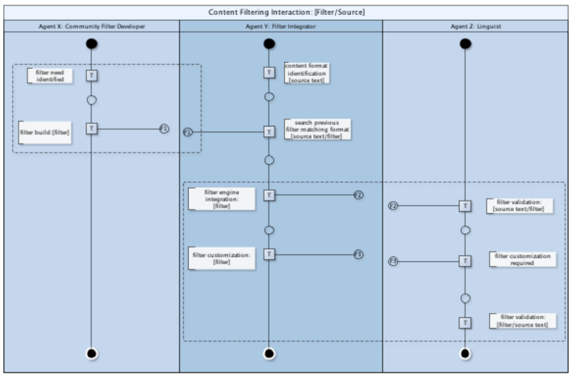


Figure 10: Content Filtering Interaction Intended Behaviors

5 Conclusions

The BWW ontology brought a piece of the answer to this research by providing a larger reference model, with the ontology, and also a methodology, in the form of the representational analysis. The model should reflect the evolution of the process from what it was to what it should be, while at the same time being able to represent all aspects of reality with fidelity. Consequently, the expectations on the capability of the notation used reflect the model function. The notation must allow the complete and precise capture, simulation and description of the business process with various levels of details from the multiple perspectives. When representing collaboration, the same issue can be found. At a higher level, the view is focused on the essential traits of the business process, and defines the goal rather than the particular objectives. At a lower level, the details of the activities to be conducted, the resources to be used and the methods are described. At the lowest level, every atomic activity of a participant, including communication, modification of an artifact, or just notification of an activity should be considered in order to reconstitute or execute the various levels alignment.

The extension proposed in this research would need to be part of a new set of specification, a grammar describing a higher level of abstraction. This grammar and its construct could then be evaluated using the BWW Ontology representational analysis method. However, in order to obtain such specification, a more detailed and formalized reference model of collaboration should be elaborated. This could be part of future research that could add to the proposed research results in this article.

Visual notation also has visual properties which might impact completeness and clarity. The visual proximity of the constructs used across the notation, but their semantic differences might impact the ability of a modeler to precisely and clearly express the abstraction of the reality. The ability of the user of the model to correctly interpret and translate the model to a particular instance of the process could also be reduced. This is usually not less an issue with formal notation, and automatic, machine-based translation of the model to scripts, but can be more problematic when the model is to be interpreted and translated into human actions. This becomes more critical in the success of human-driven collaboration because it depends on the shared understanding of all participants. In addition, most of the notations evaluated are also represented in a two-dimensional plan, while representing more than two perspectives. The current development of the three dimensional representation could also be brought into the modeling of business process. Different value perspective could then be represented at once and manipulated while having a graphical representation of the potential effects on the other perspectives represented.

It appeared that no reference model including the different perspectives on collaboration has been built yet. Collaboration between organization, collaboration between services, and human driven collaboration are part of supply chain modeling and still need a more generic reference model, an ontology of collaboration among supply chain partners. An ontology that represents better the integration of business processes would lead to the development of more integrated supply chain systems that are less likely to be disrupted because of lack of integration. From this ontology, particular instance could then be implemented and specific properties and relations built. From a business processes perspective, this would allow for a clearer specification of the collaborative view depicted and the development of specific management methodologies. From the business process notation perspective, this would allow for the definition of domain specific constructs derived from the general collaboration ontology constructs.

Future research would require to create a new set of specification, a grammar describing a higher level of abstraction. This grammar and its construct could then be evaluated using the BWW Ontology representational analysis method. However, in order to obtain such specification, a more detailed and formalized reference model of collaboration should be elaborated. A diagramming software tool with the new proposed ontology would need to be created in order to provide a tool that can be used in industry for the modeling of supply chain systems.

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