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"A Linguistic Basis For Multi-Agency Coordination"

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A Linguistic Basis For Multi-Agency Coordination

Abstract

In order to create the desired effects in a complex endeavor concerning a coalition of nations, as well as other agencies, there should be common understanding and a common intent. The creation and communication of this intent is a critical factor in the success of the endeavor, but often is overlooked. In this paper, we describe a language that expresses this common intent developed from a foundation of Command and Control (C2) business logic and generalized for Multi-Agency operations. Such a general language is not as brittle as the common message formats and data models that are currently the focus of interoperability. The abstraction of a language provides the flexibility for sharing intent and relating it to actions and reports, even if varying technology bases are brought by the organizations involved.

The language described – the Multi-Agency Operations Language (MAOL) – is composed of three types of grammars covering: 1) Intent; 2) Actions; and 3) Reports. MAOL is designed for automated processing (to support a wide range of functionality including advanced decision support tools). Because the mix of services will not necessarily be known prior to an operation, it is even more important to have a foundation of a well-structured syntax and semantics with clear operational roles defined.

Keywords: Intent, Multi-Agency Operations, Coordination, Collaboration, Planning, Linguistics

1) Introduction

Organizations that wish to achieve reconstruction, humanitarian, and peace goals must operate in a complex and unstable environment. In order for diverse and autonomous organizations to coordinate and achieve their desired effects, it is desirable for them to have a common purpose, grounding in a common understanding. However, while the concept of a commander's intent is well documented in the military C2 literature, there is no corresponding doctrine when multiple diverse agencies are operating together in a transient state.

Pigeau and McCann [2000] make a distinction between explicit intent (publicly communicated) and implicit intent (unvocalized). They then define Common Intent as "the sum of shared explicit intent plus operationally relevant shared implicit intent" [p. 172].

Previously, we have presented a formal language for C2 by defining its grammar – the Command and Control Lexical Grammar (C2LG). This language is designed for commanding and communicating with live forces, simulations and robotics [Schade & Hieb, 2006b]. We will use that work to examine explicit Common Intent [Pigeau & McCann, 2000] and determine the key issues to express and communicate it formally. In order to create Common Intent, there should already be a common understanding of the current situation We develop a formal grammar for reporting situational awareness to support reaching this common understanding. And in order to execute intent, we delineate a grammar for directing and coordinating actions – the Multi-Agency Operations Language (MAOL).

A formalization of Common Intent is particularly relevant for planning complex endeavors, given the need for rapid coordination and collaboration among geographically distributed forces. Common Intent itself is a key factor of effectiveness in a multi organization endeavor as can be concluded by the results from experiments run by Farrell [2004, 2006].

To achieve common intent, the different organizations have to communicate their explicit intent and those aspects of the implicit intent they want to externalize [Pigeau & McCann, 2000].

In order to create a common intent, different organizations participating in an endeavor will first communicate their specific intents, and then, to some extent, iterate these intents to a final statement of intent. We view our language as modeling intent to allow it to be communicated and expressed. This language is intended to support the implementation of decision support and planning tools.

1.1) Research Problem – Common Intent Among Organizations

In recent years there has been an expanded role of multi-organization endeavors for peace keeping, disaster relief and other such operations. These operations are characterized by a mix of traditional military forces, civil government forces (such as police and fire departments) and Non-Governmental Organizations (NGOs). While military doctrine drives the development and use of military C2, there is no clear doctrine or development process for multi-organization endeavors. According to the importance of developing effective information technology for multi-organization operations, there are many research activities on-going, many focused on organizational issues. In this paper, we focus on defining, creating and representing a "purpose" for such an endeavor.

Hayes [2007, p. 171] proposed a maturity ranking for endeavors. The lowest level is "conflicted" which indicates no coordination among the acting organizations. The other levels are "deconflicted", "coordinated", "collaborative", and "agile". Although we do not evaluate all of these levels here, it should be clear that on the one hand, a higher ranking sets the stage for a better result of the endeavor and on the other hand, a higher ranking demands better interaction among the acting organizations. In the case of "deconflicted" it may be sufficient to discuss and to divide the responsibilities at the start of the endeavor. In the case of "agile", however, the organizations have to share information and to coordinate on the fly in response to sudden and fleeting opportunities. Therefore, a necessary condition for an endeavor with a high maturity level is interaction and communication among the acting organizations such that they are able to build a shared awareness, a common understanding and *a common intent*. This is also stressed by Hayes [2007, p. 172] in his list of conditions an endeavor must meet to achieve success.

In this paper we focus on applying a formal language, the Multi-Agency Operations Language (MAOL), for coordination in complex endeavors. However, we do not view working at the level of "coordination" as limiting, but rather as a foundation. While we believe the MAOL will also facilitate collaboration and agility, this assertion will need to be examined in future works.

1.2) Expressing Command Intent in Current Military Operations

In our examination of Intent, we first need to define intent, describe it in a military context and finally look at how this intent can be used within operations that involve multiple diverse agencies. The concept of intent can be summarized as an expression of the purpose of an operation, where an operation is an action taken in space and time. In a military context, intent is commonly tied to a commander – the person that is in command and makes decisions. A more recent research topic is how intent can also be expressed for different organizations.

In the military, intent needs to be translated into action. A common way of doing this is an Operations Order, which is used by Coalition, Combined and Joint commands.

STANAG 2014 specifies the standard form of an Operations Order for the North Atlantic Treaty Organization (NATO). This five paragraph format is similar to that of the US and is representative of other nation's formats. Military doctrines have built on these standards, such that professional soldiers understand how an Operations Order should be structured, read and interpreted. The Command Intent statement is a key part of the format of the Order.

NATO Operations Orders are structured such that they have 5 sections (paragraphs) in the following order:

1) Situation
2) Mission
3) Execution
4) Service Support
5) Command and Signal

In the 5-paragraph order, the Command Intent statement is found at the start of the Execution Paragraph, followed by the Concept of Operations and then task-oriented directions to the forces commanded. Command Intent statements of the higher commands will be repeated in the Situation Paragraph in the section that describes friendly forces.

However, the Command Intent (and much of the Operations Order) is formatted as "free text" and as such is extremely difficult to process automatically. While a trained military professional has little problem dealing with this "free text", current automated systems handle it as a single data field and do not understand Command Intent such that they can represent or communicate it.

Proper formulation of Command Intent is essential to the successful execution of Command and Control processes, perhaps the most important element to determine a successful outcome of a military operation [Klein, 1998]. But the concept of Command Intent does not apply to multi-agency operation, as each agency or organization may have its own intent, as opposed to a traditional hierarchical military organization, where intent flows down from a higher commander to a subordinate command. In the context of a multi-agency endeavor, it is just more appropriate to call "Command Intent" simply "Intent" and, as noted earlier, define intent as the purpose of the operation. Later, we detail a grammar for Intent that closely follows the grammar defined in a military context for Command Intent, but generalize it for communicating intent between diverse organizations.

1.3) Intent related to Planning and to Complex Endeavors

There are many factors in planning complex endeavors as pointed out in Alberts and Hayes [2007]. When the scope of the endeavors is expanded to civil and non-governmental organizations, the factors become quite complex. We focus on the creation of a common intent among the different agencies or organizations involved in the endeavor. Our hypothesis is that aligning the intent between organizations will lead to a more effective result, and that this calls for coordination and communication of each actor's intent.

However, each organization may have a different intent for a particular endeavor. Thus there needs to be some representation that can both model an organization's intent and also model the degree to which intent is aligned in a particular endeavor. Even if organizations have the same understanding of a situation, they still may have different purposes when operating together.

In addition to intent, our formalism also models operations that an organization can perform and the effects these operations can have [cf. Gustavsson et al., 2008, for an approach that connects effect-based operations to the C2 formalism presented in this paper]. While effects-based planning takes these into account, we think there is a need for a more general and theoretical framework. In our work, we can model the requests that an organization can make to other organizations, as well as directives that a military organization would use.

Thus we can relate intent to actions and effects. Our formalism is particularly suited to creating simulations of complex interactions to determine courses of action. However, it also is unique in representing and providing a calculus for intent and actions.

1.4) Linguistics applied to Complex Endeavors

In order to communicate, a language is needed Alberts and Hayes [2003, pp. 112ff.]. Pigeau and McCann [2000, p. 168] also refer to a common language as a basis for sharing explicit intent (cf. subsection 2.1 for a discussion of the difference between explicit and implicit intent as proposed by these authors). In many international endeavors the common language of choice is English. However, although many people involved in international multi-organization endeavors speak English (to some degree), English often is not their mother tongue or – even if they share English as mother tongue, people might belong to organizations with a different background or a different culture. Natural languages are not free from ambiguities and lack of precision. Thus, the interpretation of natural language expressions, may depend on subtle nuances that non-native speakers often do not catch or that can only be understood under a specific cultural orientation. This may result in misunderstandings that endanger the endeavor. In our paper, we will offer a solution to this problem. We will propose a formal language following English that on the one hand is unambiguous and allows for a clear interpretation. On the other hand, the proposed language will be expressive enough that it can be used to share information, to share awareness, to share understanding, and to share intent. There is an additional benefit: As the language is an unambiguous and *formal* language, its expressions even can be analyzed automatically. This is of high worth when the endeavor is distributed and supported with modern information technology.

In our previous work with the C2LG, we used the semantics of the Multilateral Interoperability Programme (MIP) for C2 terms relevant for coalition operations. These semantics are documented in NATO in the Joint Command, Control and Consultation Data Exchange Model (JC3IEDM) [MIP, 2008]. While the JC3IEDM consists of a Data Model intended to represent the

core data types identified for exchange across multiple functional areas, it is primarily concerned with coalition forces.

Because of the military emphasis of the JC3IEDM, it is not appropriate, at this time, to expect NGOs or other non-military agencies to implement the JC3IEDM. Thus, the strong semantics enforced by the use of the JC3IEDM cannot be expected in complex endeavors. However, the linguistic approach towards communication and coordination outlined in this paper could serve as a useful framework toward better coordination and collaboration in Multi-Agency Operations.

In the future, the JC3IEDM standard semantics may be extended and generalized to cover non-military operations (such as disaster relief). We view the additional effort of developing a language as still necessary, and in [Schade & Hieb, 2006b] we presented an analysis on why only relying upon a data model is insufficient even for military communication.

Interoperability has proved to be a challenging area for the military, where functionality is, of necessity, more important than standardization. There is a need for new approaches to interoperability to complement the revolution in military technology taking place through Network-Centric approaches [Alberts and Hayes, 2003]. Applying the science of linguistics to the implied ontologies emerging from programs like the MIP is an innovative, and potentially more viable approach than the ones previously used.

1.5) Current Research in Linguistics for Command and Control

There has been much interest in developing an unambiguous C2 protocol in order to support interfacing between Simulations and C2 systems. This work has been called Battle Management Language (BML). Initially, BML was based on relating 5 "Ws" (Who, What, Where, When & Why) in an "informal" grammar as described in [Carey et al., 2001]. Coalition Battle Management Language" (C-BML) is a standards initiative currently being pursued within the Simulation Interoperability Standards Organization (SISO) and is described in [Blais et al., 2005]. NATO has established a Technical Activity (MSG-048) to also investigate a C-BML. The NATO working group has used an implementation of BML based upon the C2LG for communication between C2 systems provided by Norway, the Netherlands and the US to simulations provided by France, Spain and the US [de Reus et al., 2008; Pullen et al., 2008]. MSG-048 has a total of 10 member nations. This experience is providing many lessons in implementing a formal language for communications between military organizations and is relevant to developing a language for multi-agency coordination. The C2LG BML has also been used for communication in multi agent environments [Hügelmeyer et al., 2007; Borgers et al., 2008] and for developing specific web services [Pullen, Levine & Hieb, 2008].

1.6) Organization of the Paper

In Section 1, we examine the research problem of defining common intent between organizations. Section 2 looks at the concept of intent, and how this concept is created and used. Section 3 presents the theory taken from Computational Linguistics that underlies our work with formal grammars, as well as previous work that developed C2 grammars. In Section 3 we present the MAOL grammars for tasking, reporting and expressing Intent. Section 4 presents a case study of common intent in Multi-Agency Endeavours, and Section 5 presents an analysis of the case study in respect to coordination, collaboration and agility.

2 Creating Intent

Before we describe our formalism, we must first describe our concept of intent in more detail, and in the context of complex endeavors between various diverse organizations.

2.1) Defining Intent

Alberts and Hayes discuss intent in "Understanding Command and Control" and distinguish between Intent, Command Intent, and Commander's Intent [Albert & Hayes, 2006]. Commander's Intent implies a single individual in command, while Command Intent is a term that implies a group or collective making decisions. The term "Intent" is more general yet. In this paper we use Intent, a concept indicating a purpose that is similar to but not the same as Command Intent. Intent is broader in meaning than Command Intent, as it does not assume a command relationship.

With respect to military operations, the United States Department of Defence (DoD) defines Commander's Intent as [DoD, 2005]

"a concise expression of the purpose of the operation and the desired end state that serves as the initial impetus for the planning process. It may also include the commander's assessment of the adversary commander's intent and an assessment of where and how much risk is acceptable during the operation."

The US Army in Field Manual 3-0, Operations [USA, 2001], similarly defines Commander's Intent as:

"A clear, concise statement of what the force must do and the conditions the force must meet to succeed with respect to the enemy, terrain and the desired end state."

This is expanded in Field Manual 5-0, Army Planning and Orders Production [USA, 2005], which specifies that the Commander's Intent links the mission to the concept of operations, describing the end state and key tasks that are the basis for subordinates initiative, along with the mission. In addition, the Commander's Intent should convey a broader sense of purpose, giving the context of the mission. Doctrine also says that the mission and Commander's Intent should be understood in lower echelons (either one or two levels down).

In accordance with this definition, FM 5-0 breaks down Commander's Intent into these three elements:

- End State;
- Key Tasks;
- Expanded Purpose.

The concept of Intent must capture the essential elements of a mission's goal and objective. The DoD definition also assumes a formal planning process, which may not be present in future operations. As we are concerned with transitioning and putting into place a new C2 Language, we will concern ourselves with a design that accommodates both a formal planning process as well as situations where the planning is done in a more distributed and parallel fashion.

Pigeau and McCann [2000] make a distinction between explicit intent (publicly communicated) and implicit intent (unvocalized). They then define Common Intent as "the sum of shared explicit intent plus operationally relevant shared implicit intent" [p. 172]. Implicit intent is that which goes without saying. It is based on personal expectations, military expectations, and cultural expectations [ibid, p. 166], e.g., the expectation of modern western societies (post heroic societies) [Münkler, 2006, chapter 16] to avoid casualties for their own troops in military operations. In communication, hints as to implicit intent are often provided by those nuances of language that only native speakers that belong to the same cultural group notice (e.g., to the same military service or even to the same regiment) (cf. subsection 1.4). Language that hints at implicit intent is shaped by socialization [cf. Pigeau & McCann, 2000, p. 171]. Our work with MAOL is on the level of explicit intent, and even sharing this is "a remarkably complicated and error-prone activity" [ibid, p. 168]. However, meeting the requirements of MAOL, namely to provide a basis for the communication of all those aspects that are of importance for the endeavour, at least some aspects of the implicit intent have to be externalized – one of the four methods Pigeau and McCann suggest for sharing implicit intent [ibid, p. 171]. MAOL does this by integrating these aspects into the representation of explicit intent. Therefore, some of the MAOL expressions in the example of chapter 4 may look extremely detailed and redundant. Gustavsson et al. [2008] offer an alternative. They propose a specific constituent in their definition of intent called "Expressives" to represent externalized implicit intent.

2.2) Coordination and Intent

In order to build intent, and develop a formal language for coordinated operations, there must also be a component of the language that builds common understanding of the problem being faced. While the problem may be well-understood in military organizations, it is quite challenging for multi-agency endeavors. We address this by specifying a grammar for reports, in order that organizations may communicate their situational awareness both prior to and during operations.

Similarly, coordinated operations consist of decisions made jointly and actions taken to achieve desired effects. We link actions to effects in our linguistic approach and thus can deal with either traditional mission planning or effects-based planning. In traditional planning, once intent is stated by organizations, multiple courses of action are developed that produce effects to achieve a desired end state. Effects-based planning in contrast looks at the desired end state to determine the effects required and then infers the actions and units required to achieve the effects identified. In either case, we model intent, actions, effects and end states. Farrell [2007] proposes that the desired situation (Intent, mission/strategic objectives, etc.) is decomposed into desired effects. The desired effects can be decomposed into sub-effects, and so on. Finally, a desired action is associated with the lowest level desired effect. Those desired actions could be further decomposed into sub-actions. The result is a hierarchical decomposition of intent in terms of the intended situation (i.e., end state), intended effects and intended actions. This approach can be modeled with the grammar we have developed. We propose a grammar for actions that covers not only traditional military orders but also directives from one agency to another as well as requests.

In establishing common intent, we realize that organizations may start out with different objectives and may never reach a common intent among all organizations.

3 A Linguistic Basis for Intent

In linguistics, a (formal) language is defined by a grammar. In short, a grammar is a quadruple. It consists of a set of so-called "terminal symbols", a set of "non-terminal symbols", a starting symbol that is part of the set of non-terminals, and a set of production rules. The terminal symbols are the words of the language in question. Thus, the set of terminal symbols is nothing less than the language's lexicon. The other main component of the grammar is the set of rules. The rules define how the lexical elements can be combined.

In the following, we will explain how a grammar works. Let us assume that there is a statement within a communication, e.g., a single line of a directive. ("Directive" here is a meant as a linguistic term, not a military term. This means, that a directive is defined as an utterance by which the sender urges the addressee to take action. Cf. section 3.2 for more details on linguistic classification of utterances.) In order to analyse it, multiple steps have to be undertaken. First, the statement has to be parted into constituents. Constituents are groups of words that belong together. The 5 Ws (Who, What, Where, When, Why) are constituents. For example, in the directive "*advance to area Alpha as soon as possible*", the words "*to area Alpha*" form a constituent that can be categorized as a Where. Constituents are arranged in a hierarchy. In our example, "*to area Alpha*" is subordinated to "*advance*" as it provides the Where (or better the destination) of the advance action.

In natural language processing, the second step in the analysis is to assign syntactic labels to the constituents, e.g. "subject." After that, in a third step, a second label is assigned to each constituent, a label that expresses the semantic (or thematic) role of the constituent in question. In our example, the constituent "*to area Alpha*" could be labelled "Where" or better "destination." One of the problems that have to be taken into account in natural language processing results from the fact that the semantic structure is not easily derived from the syntactic structure [Nirenburg & Raskin, 2004, pp. 106f.; Sadock, 2003]. For example, in both statements "Lightning struck Martin" and "Martin was struck by lightning", "Martin" receives the semantic label "patient" (the one who is affected by the action) although it bears the syntactic labels "direct object" in the first statement and "subject" in the second whereas the "subject" of the first statement is "lightning." By defining an artificial language, one can avoid the problem of the syntactic-semantic mismatch. The language can be built in a way such that it is possible to assign semantic labels directly to the constituents, that is, without a step in between using syntactic labels like "subject" or "object." The assignment can be based on word sequence and on key terms. A good system of these labels has been proposed by Sowa [2000, p. 506ff.]. These labels are more fine-grained than the general BML labels Who, What, Where, When, Why. For example, there are four labels of type Where, namely location (*stay* ***at control point Charley***), source (*leave* ***control point Charley***), destination (*advance* ***to control point Delta***), and path (*advance* ***along route Beta***).

In sum, our aim is to define an artificial and formal language for multi-agency communication that is easily processed automatically. This processing is in two steps. First, constituents are identified. Second, each constituent is labelled by a semantic label whereas the set of semantic labels denote the thematic role the labelled constituent plays. Technically, the expressions of our language will be transformed into XML documents in which the constituents form the contents of the elements and the labels are used as tags. In this form, the semantics of an expression can easily be interpreted automatically.

In the reminder of this paper, we will present such a formal language, the MAOL. The language follows in general aspects our version of a Battle Management Language (BML) and its grammar follows grammars developed for the C2LG (Command and Control Lexical Grammar) [Schade & Hieb, 2007b]. However, in contrast to the BML, the MAOL will account for the fact that the organizations operating together in an endeavour are less coupled than military forces that cooperate in a combined military operation. The rest of section 3 is organized as follows: In 3.1, we will give a short overview of the linguistic principles we have considered in constructing the language. In 3.2, we will discuss how to formulate directives, as well as how to formulate commissives (expressions by which the sender commits himself to some course of action); in 3.3, we will discuss how to formulate reports (assertives by which the sender expresses that something is the case); and in 3.4, we will discuss how to formulate intent.

3.1) ***Linguistic Principles***

As has already been stated, a language is defined by a grammar. The rules of the grammar chosen are rules that express how to group words into constituents. The rules therefore form the basis for the first step of analyzing a language expression. The theory of linguistics categorizes grammars into four types that form the Chomsky hierarchy [Chomsky, 1957; Partee, ter Meulen & Wall, 1990, section 16.5]: grammars of type 0 (unrestricted grammars), of type 1 (context-sensitive grammars), of type 2 (context-free grammars), and of type 3 (regular grammars). The types of rules used define the type of the grammar. Only grammars of types 2 and 3 exclusively consist of rules that can easily be applied by automated systems. Thus, only these kinds of grammars can be automatically processed. Therefore, our language has to have a grammar of type 2 or 3. Grammars of type 3 (regular grammars) only allow two types of rules "A → *a*" and "A → *a*B". Here "*a*" represents a terminal symbol (a word) and "A" and "B" represent non-terminal symbols.

Thus, a regular grammar expands a non-terminal symbol either to a word or to a word plus another non-terminal symbol. Our example directive "*advance to area Alpha as soon as possible*" should however be divided into three pieces, namely "*advance*", "*to area Alpha*", and "*as soon as possible*". We therefore would like to have a rule like "Directive → Task Where When" such that Task can be expanded into "*advance*", Where can be expanded into "*to area Alpha*", and When can be expanded into "*as soon as possible*". Such a rule, however, is not a regular rule, but a context free rule. Using a regular rule, as we would find in a regular grammar, the example directive would need to be built with several rules, incrementally. Thus, a regular rule that can start the parsing of our directive could be "Directive → *advance* Non-terminal-1". In contrast to the non-terminal symbols Task, Where and When we used for the context free rule, in the regular rule we have the meaningless symbol "Non-terminal-1". Even worse, we would need an even more meaningless rule "Non-terminal-1 → *to* Non-terminal-2" to go on with parsing followed by the equal meaningless rule "Non-terminal-2 → *area* Non-terminal-3" and so on. Obviously, regular rules have to be expressed with meaningless non-terminals whereas context free rules use non-terminals that represent semantic labels like Where or When. In sum, our language has to have a grammar of type 2 such that the constituents resulting from the first step of analysis can be assigned semantic labels in the second step. For this reason, it is not adequate to use a regular grammar to define formal languages for military communication, although the contrary has been asserted by Tolk et al. [2007].

In order to optimize the assignment of semantic labels (analysis step 2), we incorporated the following linguistic principles (in addition to using a grammar of type 2) in our language:

- Lexicality,
- Coherence, and
- Completeness

Lexicality means that the rules are based on lexical elements. In particular, the use of a specific verb as task verb in a directive, in a commissive or in a task report results in the use of a rule that is based on that verb's frame (cf. [FrameNet]). The frame determines what kind of constituents must, which kind of constituents may, and which kind of constituents may not follow the tasking verb. Completeness means that a constituent demanded by the frame has to be present, and Coherence means that no constituent can be part of an expression that is not at least marked as optional by the frame. With these principles in mind, we can now present our language.

3.2) Directives and Commissives

In the military field, units give discrete orders to subordinate units. By definition, orders must be executed by the addressee. Complex endeavors do not have the classical strict command chain of military forces. Thus, it is not appropriate to send orders in complex endeavors. In linguistics [Searle, 1979], the term "directive" is used for an expression that has the purpose to get the addressee to do something. In this sense, orders and requests are directives as are pleas or even challenges [Levelt, 1989, pp. 60f.]. For our formal language for complex endeavors, we will use the term "order" with its standard meaning: The addressee of an order has to execute the ordered action. Orders are only used in the case that a military force with classic command structure is part of the endeavor and if the order is given along this chain of command. In all other cases, we will differ between "tasking" and "request". In our language, a tasking is given if the sender expects the addressee to do as directed. In the case of request, the decision to act or not stays at the addressee. In short, we use "order", "tasking", and "request" as directive's subcategories.

The basic expressions of the MAOG for directives are taken from the C2LG [Schade & Hieb, 2006a, b]. C2LG's basic order rule, abbreviated as OB, has the form (1).

(1) OB → Verb Tasker Taskee (Affected|Action) Where
Start-When (End-When) Why Label (Mod)*

In this rule form, Verb is the tasking verb, e.g., advance or attack; Tasker is the one who orders the task; Taskee is the unit that has to execute it; Affected and Action denote who is affected by the task (either an object – Affected – such as an enemy unit in the case of attack, or another task – Action – such as that attack in the case of assist); Where is the location the action takes place (that can be a place or a route); Start-When is the point in time when the task has to start; End-When is the point in time when it has to end (this constituent is facultative); Why provides a reason for the task (it is linked to the intent); Label is a kind of ID that can be used to refer to this order; and through Mod some modifiers can be added. More details are given in [Schade & Hieb, 2006a, b].

In order to use rule form (1) for the MAOG as rule form for basic directives (DB), we have to add a term that indicates whether the expression is an order, a tasking, or a request. This term is called categorization term (CatT), and it can expand to the key words "order", "tasking", or "request."

(2) DB → CatT: Verb Sender Addressee (Affected|Action) Where Start-When (End-When) Why Label (Mod)*

In a complex endeavour, it is necessary to coordinate the actions of the different organizations. In the MAOG, there are two language instruments to ensure this coordination. First, it is required that the receipt of an order, of a tasking, or of a request is confirmed. This is done by a basic statement of confirmation (CONB, rule (3)). In (3), the categorization term is either "order-confirmation", "tasking-confirmation", or "request-confirmation", and the label is the label of the directive confirmed.

(3) CONB → CatT: Label

In addition, there is a specific form of confirmation. If a unit that is integrated in some kind of a command chain, e.g., a police unit, starts an action that is not directed by its superior – a typical behaviour in an agile organization – it has to report this to its superior. This is done by a task report as will be presented in subsection 3.3. In this case, the superior has to confirm the receipt of the report. This confirmation is again expressed by a basic confirmation using the form of (3), with the categorization term "task-confirmation".

The second instrument to ensure coordination is the use of commissives. It is desirable that every organization knows about the tasks other organizations actually execute or intend to execute in the (near) future. Therefore organizations can communicate their intent to execute tasks, e.g., to prevent other organizations from taking redundant actions. Such announcements are well structured in the MAOG and may be created quickly, without much overhead. Various business logics can be implemented, (such as "tasks that are not vetoed by another organization will be binding"). In our language, an announcement to execute a task is a commission. Basic commissions (COMB) follow rule form (4). This rule form is nearly identical to (2) with two exceptions. First, it has "commission" as categorization term and second, instead of two unit constituents (Sender and Addressee) there is only one, namely Executer that denotes the unit that will execute the task.

(4) COMB → **commission**: Verb Executer (Affected|Action) Where Start-When (End-When) Why Label (Mod)*

Normally, an organization will commit to an action if this action has been directed. Nevertheless, we believe it is not sufficient to use rule form (3) for commissions. In a complex endeavour, an organization may receive a directive and therefore commit itself to an action, but the chosen action may differ from what has been requested or tasked. For example, the acting organization may start the action later than requested. In order to connect a commission to a directive, the modifier constituent (Mod) can be used. The respective modifier consists of the keyword "**regarding**" and a label (Regarding_Label) where Regarding_Label is to be instantiated by the label of the directive that had caused the commission.

*3.3) **Reports***

The C2LG rules for reports in the military context have been introduced in [Schade & Hieb, 2007a]. For MAOL, we will use these rules for reporting. We therefore will only give an overview here and refer to that source for more details. However, we will add a rule in order to illustrate how our previous work is expanded with respect to complex endeavors.

The MAOL main rule for reporting says that a report consists of arbitrary many basic reporting expressions (RB). The general form of a basic reporting expression depends whether the report is about military operations (task report), events (event report) or status (status report). The basic rule for a task report is given in (5a), and the basic rule for an event report is given in (5b). Analogous to the basic rules discussed so far, a basic reporting expression starts with a categorization term followed by a double colon ("Task-Report:" and "Event-Report:", respectively).

(5a) RB → **task-report**: Verb Executer (Affected|Action) Where When (Why) Certainty Label (Mod)*

(5b) RB → **event-report**: EVerb (Affected|Action) Where When Certainty Label (Mod)*

Status reports can differ with respect to the kind of status they describe. In [Schade & Hieb, 2007a], we discussed position reports, reports about the general status of a military unit, reports about the status of persons, and reports about the status of material. With respect to complex endeavors, there have to be additional types of status reports, e.g., reports about the status of buildings (facilities) in the case of a disaster relief operation after an earthquake or a flood. As other MAOG expressions, status reports begin with a categorization term and a double colon. The general rule for a report about the status of a building therefore is (5c):

(5c) RB → **status-building-report**: Identification Status-Value (Where) When Certainty Label (Mod)*

In (5c) Identification expands to an expression that refers to a building (or more generally to a facility). Status-Values describe the status of the building. Possible status values are "not damaged," "slightly damaged," "moderately damaged," "extensively damaged," "completely damaged," and "collapsed." In the case of "collapsed" more detailed terms may be used like "pancake collapse – several stories." As in every basic report rule, (5c) includes a Where, referring to the location of the object the report is about, a When that specifies the point in time when the report had been valid, a Certainty that specifies the likelihood of the report from the sender's perspective, a Label that can be used to refer to the report, and the possibility to add modifiers. In contrast to other reports, Where is not mandatory in status reports about buildings because in contrast to persons, units and vehicles (material) buildings do not move. Thus, if Identification refers to the building in question unambiguously, it also refers to its location.

The rules discussed so far provide the basis for the formalization of Intent as can be seen in the next subsection.

*3.4) **Intent***

With respect to military operations, Intent can be broken down to the elements (desired) end state, key operations, and expanded purpose. Of these elements, only the End State is mandatory. The Key Tasks are those tasks that the commander views as essential for the operation to succeed and serve as the basis for subordinates' initiative. Therefore, we defined (6) as a general rule for Command Intent [Hieb & Schade, 2007]:

(6) CI → [Expanded Purpose] [Key Tasks] [End State]

Since the elements describe terms that are not specific to military operations, but hold for all kind of operations, we will use this rule also in the MAOG. Only a simple modification had been made. We assume that describing the desired end state is sufficient for formulating an intent. Thus, the elements key tasks and expanded purpose are facultative in the MAOG.

(7) Intent → ([Expanded Purpose]) ([Key Tasks]) [End State]

As we have already argued with respect to the C2LG, the formulation of key tasks follows the rules of orders and the formulation of the expanded purpose as well as of the desired end state follows the rules of reports. The most important aspect of the latter is that a report that describes a desired end state (or a purpose) reports it as fact for at some future point in time.

In order to create a common intent, the different organizations participating in the endeavor must first communicate their specific intents. Second, they may, to some extent, iterate these intents to a final state. As a quite simple negotiation method, for example, each organization might declare which parts of the other organizations' intents it agrees to. The agreement can be declared in two ways. First, an organization could commit itself to assist a key task of another organization. Second, it could add a desired state proposed by another organization to its own desired end states. In the intent, single key tasks as well as single desired end states and single expanded purposes are assumed to be listed by importance (the first one is the most important). Thus, an organization that agrees to some part of another organization's intent could propose changing the priority of a particular end state expression to indicate how important the end state is in comparison to its own desired end states.

In the following section we will present a case study with statements of intent, a commitment to assist a key task of another organization and some lines of operational communication and their translation into Coordinated Operations Language expressions.

4 Communicating Common Intent – Case Study

In order to illustrate how the C2LG formalism can be applied, in this section we will give an example. The example is based on the disaster response exercise ATLAS 2007 [Gehbauer et al., 2007] organized by the Civil Protection of Romania and the German Collaborative Research Center 461 "Strong Earthquakes". In this exercise, an earthquake in the Vrancea region occurred that caused buildings to collapse in Bucharest. The assumed earthquake used the parameters of a real earthquake that struck the Vrancea region in 1977. The resulting damages in the exercise

were calculated on the basis of these parameters and the current building structures of Bucharest. In ATLAS 2007, an Emergency Operations Center (EOC) coordinated the operation. The organizations involved were the civil protection organization of Romania, running the EOC as well as response teams for Urban Search and Rescue, Red Cross, gendarmerie and police units, and representatives of public companies being responsible for critical infrastructure such as telecommunications, public transport, and electricity.

In our example, the setting is moved to a less stable and less organized region. State Arga is ruled by a weak government. The separatist movement CILL operates in Arga's Ibra province to found their own state. Arga is supported against CILL by its much stronger neighbour state Barca because Barca fears that CILL might expand its influence into Barca's own province Novorro, bordering Ibra. The center of the earthquake is near the city of Surgant, the provincial capital of Ibra. Arga deploys a governmental civilian EOC with response teams. Also on hand are also Surgant's fire brigades and police units. In addition, Red Cross is present, as is a military force of Barca that can provide rescue helicopters and heavy engineering equipment like cranes and bulldozers.

In short, the EOC and its response teams intend to find buried people and rescue them. They also intend to classify the buildings according to the HAZUS standard [National Institute of Building Sciences, 1997] to ease further operations. Finding and rescuing persons is also in the intent of the other participating organizations. It is in the focus of the Red Cross, of course. In addition, the fire brigades want to extinguish all fires that may have broken out; police units want to prevent looting and vandalism; and the military force of Barca wants to stop CILL exploiting the situation by further destroying governmental property or even bombing the rescue teams.

In the MAOL, EOC's intent is expressed as:

[key tasks]:

Rescue civilians in Surgant beginning at time October 2, 2007 at 0800.

rescue EOC OPEN civilian **at** Surgant **start at** TP1 label-kt-01;

Determine building damage and identify those buildings that need to be evacuated in Surgant beginning at time October 2, 2007 at 0800.

classify EOC OPEN facility **at** Surgant **start at** TP1 label-kt-02;

[end state]:

The end state of this operation is that all civilians in danger as a result of the earthquake are safe by October 5, 2007 at 0800.

rescue OPEN civilian **at** Surgant **end at** TP9 RPTFCT label-es-01;

In intent OPEN is a placeholder for a unit the EOC can direct, some of its response teams. The terms civilian and facility denote classes of objects, and TP1 and TP9 are points in time that correspond to the beginning and the end of the operation, respectively. Barca's military force (MilHQ) agrees to the rescuing of the civilians as part of the common intent, and its leader sends the following commitment:

commission: ***assist*** MilHQ EOC label-kt-01 **at** Surgant **start at** now;

In the following, some lines of communication of the operation are given. Natural language communication is given in italics. In each case it is followed by the corresponding MAOL expression.

Response Team D to EOC:

Building Melkart Street 1 (Building 2109) is moderately damaged.

status-building-report: Building 2109 moderately damaged **at** now RPTFCT label-r-01;

Remark: The credibility "RPTFCT" translates to "reported as fact". This is an expression taken from the JC3IEDM.

Response Team D to EOC:

Heard Help Cries at Building Melkart Street 1 (Building 2109); 5 buried persons located.

Begin rescuing.

status-person-report: 5 neutral civilian (label C5) buried **at** Building 2109 **at** now RPTFCT label-r-02;

task-report: ***rescue*** RT-D C5 **at** Building 2109 **start at** now RPTFCT label-r-03;

Remark: The constituent "5 neutral civilian" is labeled "C5". The label is a unique ID such that the persons denoted by "5 neutral civilian" can be unambiguously referred to by "C5" in the subsequent communication.

EOC to Response Team D:

OK. Response D, you are at Building 2109, rescuing 5 buried people.

task-confirmation: label-r-03;

Response Team D to EOC:

4 people rescued at Building 2109; 1 rescued person badly hurt; medical support needed.

task-report: ***rescue*** RT-D 4 of C5 **at** Building 2109 **end at** now RPTFCT label-r-04;

status-person-report: 1 of C5 (label C28) wounded **at** Building 2109 **at** now RPTFCT label-r-05;

request: ***support*** Medical-Team RT-D **at** Building 2109 **start asap** now label-d-01;

Remarks: The constituents "4 of C5" and "1 of C5" refer to a subset of the object (five persons) denoted by "C5". The latter subset – 1 of C5 – now receives its own label, namely C28. The term "wounded" is taken from the JC3IEDM, table "person-status-physical-status-qualifier-code". However, in real disaster relief operations, a medical standard like the Manchester Triage System [Mackway-Jones, Marsden & Windle, 2005] would be preferable. The constituent "start asap

now" translates to "start as soon as possible, at best at now". "asap" is a temporal modifier introduced by the JC3IEDM.

EOC to Response Team D:

Confirmation. Response D at Building 2109; 1 rescued person badly hurt; medical support requested.

request-confirmation: label-d-01;

EOC to RedCross:

1 rescued person heavily hurt at Building 2109; request medical support.

status-person-report: 1 neutral civilian (label C28) wounded **at** Building 2109 **at** now RPTFCT label-r-06;

tasking: ***support*** Medical-Team RT-D **at** Building 2109 **start asap** now label-d-02;

RedCross to MedicalTeamF

1 rescued person badly hurt at Building 2109; support rescue team there.

status-person-report: 1 neutral civilian (label C28) wounded **at** Building 2109 **at** now RPTFCT label-r-07;

order: ***support*** MedicalTeamF RT-D **at** Building 2109 **start asap** now label-d-03;

RedCross to EOC:

Medical team is moving to Building 2109.

tasking-confirmation: label-d-02;

commission: ***support*** MedicalTeamF RT-D **at** Building 2109 **start at** now label-c-01 **regarding** label-d-02;

Rescue Team D to EOC:

1 person still buried at Building 2109; request crane

status-person-report: 1 of C5 (label C33) buried **at** Building 2109 **at** now RPTFCT label-r-08;

request: ***support*** OPEN RT-D **at** Building 2109 **start asap** now **by** crane label-d-04;

Remark: The modifier constituent "**by** crane" means that the requested unit (OPEN) should have a crane needed to fulfill the requested task.

EOC to MilHQ

1 person buried at Building 2109; request crane.

> **status-person-report**: 1 neutral civilian (label C33) buried **at** Building 2109 **at** now RPTFCT label-r-09;
>
> **request**: ***support*** OPEN RT-D **at** Building 2109 **start asap** now **by** crane label-d-05;

This is a critical decision point in the exercise. The military commander of Barca 's forces has to decide whether he will order his engineering unit to move a crane to Building 2109 to support the response team and the Red Cross rescuing the buried person. His decision will depend on the activities of CILL. His prime goal is to prevent CILL activities (such as looting, vandalism, kidnapping or even more violent acts like shooting or bombing). Rescuing persons (and thereby supporting his partners to reach their prime goal) is only a secondary goal for him. Thus, accepting the request will depend on whether he needs the engineers and their cranes to defend against the CILL. If not, he will most probably send the crane:

MilHQ to EngUnit

1 person buried at Building 2109; rescue person by crane.

> **status-person-report**: 1 neutral civilian (label C33) buried **at** Building 2109 **at** now RPTFCT label-r-10;
>
> **order**: ***rescue*** MilHQ EngUnit C33 **at** Building 2109 **start at** now **by** crane label-d-06;

MilHQ to EOC:

We will move crane to rescue civilian at Building 2109

> **request-confirmation**: label-d-05;
>
> **commission**: ***rescue*** EngUnit C33 **at** Building 2109 **start at** now label-c-02 **by** crane **regarding** label-d-05;

5 Discussion

Obviously, the endeavor described so far is not agile. However, the communication methods that were enabled by the language we defined are necessary to grant the given level of cooperation. It is necessary for the coordinating center to have directives at hand to coordinate the activities of its rescue teams. It is necessary to have requests at hand to ask the other organizations for resources and for help. Requests will have a better chance of being accepted if the requested help and the requested resources are used for goals that the organization sending the help has agreed to. Thus, it is necessary to coordinate the goals, which is done by exchanging intent. Last, it is necessary to answer directives and, even more important, to answer requests. This confirmation is not strictly necessary with respect to classic military forces (although it is good practice in classical military communication, too). Classically, in a traditional military process there are orders that have to be executed. In contrast, with respect to directives and requests, it is the addressee who decides whether he will act as the sender wants him to act or not. Therefore, it is important for the sender (of the directive or of the request) to know whether the addressee will act

as requested or not. The sender's own actions depend on that knowledge. So, the answers to the directives and the requests as they are enforced by the language – these are the commissives (and their negative versions) – drive the interplay of the different organizations in the endeavor.

All of the communication acts discussed also play a role (or play a greater role) if the endeavor evolves towards agility. One minor difference between a coordinated approach as the one described in the case study and a collaborative (or even an agile) approach would be that the information flow is more network-centric. Under network-centricity, reports would not be sent to a specific addressee but published in the network. Thus, reports about the same facts, e.g., the reports with the labels "label-r-05" and "label-r-06" in the example in Section 4, would become one. In order to illustrate further consequences of a more agile endeavor, let us discuss two variants of the case study.

First, let us assume that the Red Cross had not agreed to work for the EOC directly. In this case, what had been taskings to the Red Cross are now requests. This of course is not a step towards agility by itself. However, the Red Cross will be part (a node) of the general communication network. So, as soon as the response team starts its action to rescue the buried persons, the Red Cross can assume that some of these persons most probably will be hurt and need treatment. As they will know (as part of the endeavor), response teams do not have sufficient resources to treat persons that are moderately injured or worse. Thus, the Red Cross – under the assumption that they have resources available – can send a medical team to Building 2109 as soon as the response team reports its starting action. Of course, Red Cross has to communicate this sending of a medical team such that all other organizations of the endeavor see this action in the shared operational picture and can react accordingly. In principle, this step towards agility may save valuable time: The medical team reacts directly whereas in the "coordinated" situation its action has to be directed.

Second, let us take a look at the military forces. A military commander, seeing rescue actions begin at Building 2109, might have to analyze the military situation as well. A coordinated rescue action by a response team of Arga and by a Red Cross medical team (and in addition by a crane belonging to Barca's engineers) might increase the chance of a violent reaction (e.g., an attack) by the CILL. Thus, the military commander might send a protection force as soon as he learns about the rescue action. While the military aspect may not be in the common intent of all of the organizations involved, the military commander may judge that this is necessary to execute his organization's intent.

6 Conclusion

We have developed a formal language, based on a synthesis between computer science, information science and linguistics, for conducting a class of operations through space and time. The language is designed for different entities and diverse organizations.

As seen by recent work with the C2LG [Schade & Hieb, 2006b], we believe that using these grammars and a linguistics-based approach to develop more flexible and capable models will enable the communication languages currently used to be more capable of supporting not only coordination, but collaboration and agility as well.

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