A Note on Modelling Speech Acts as Signalling Conventions

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Abstract. This paper presents a fully formal integration of Jones's logical theory of speech acts as signalling conventions with Kimbrough's Formal Language for Business Communication (FLBC). The work is part of a larger programme of logicism in the context of electronic commerce. Speech acts are an especially apt subject for this programme because of their pervasiveness and importance in communication for all commerce, electronic or not. The paper demonstrates that the conventionist view of speech acts, embodied in Jones's logical theory, fits naturally with Kimbrough's FLBC and with the Basic Messaging Framework for business communications. Further, the paper provides an illustration of how the resulting integrated theory might be implemented in practice through logic programming.

1 Introduction

A logicist may hold any of several views on the role and value of formal logic in electronic commerce. Prominent among these views are:

- Formal logic is a useful, perhaps even preferred, tool for analyzing and clarifying concepts of import in electronic commerce.
- Formal logic is a useful, perhaps even preferred, tool for articulating important kinds of specifications pertaining to electronic commerce. Among these kinds are specifications for designing ma-chine-to-machine messaging systems.
- Logic in the applied form of logic programming is potentially a valuable, perhaps even preferred, vehicle for implementation of machine-to-machine messaging systems.

We are logicists, at least in the context of electronic commerce, and we believe that there is much to be said in favor of each of these views. Too much in fact to fit into a short paper. Our present ambitions are more limited. We aim to sketch a formal and logical theory of speech acts as conventional signalling acts. In virtue of being formal the theory affords rigorous, machine-readable representation. In virtue of being logical a well-defined and justified formal inference apparatus is part of the theory. Our strategy for constructing this

theory is to combine Kimbrough's FLBC theory[1] with Jones's theory of conventional signalling acts and its attendant logical framework.[2] Kimbrough's FLBC theory is a representational theory, in first-order logic, that is apt for expressing signalling acts (among other things). It is not, however, an account of what signalling acts are, of what constitutes them. Jones's theory of conventional signalling acts is such an account. With proper attention to details, the two theories fit together hand in glove, as we shall explain.

Speech acts are of fundamental import and enduring interest for electronic commerce, and generally for understanding language and communication. The concept of the speech act is well entrenched in a number of disciplines, including linguistics, philosophy, the computational sciences generally, and particularly in the thinking of researchers in electronic commerce. The underlying notion—originating with Austin [Aus62] and further developed by Searle [Sea69] and others—is that speaking is a kind of doing or acting, and that we should consider the broad range of kinds of things that agents can do with words, rather than one-sidedly focusing on acts of stating that such-and-such is the case.

Speech acts are interesting theoretically because they seem to be so pervasive in language, and because of the logical and conceptual challenges in developing a workable formal theory of them. These two factors also motivate the practical interest in speech acts, evidenced by researchers in electronic commerce. Pervasive in commercial transactions are mundane communications—purchase orders, invoices, receiving reports, etc.—that are required in great volume and that should be, all agree, very profitable targets for formalization and automation. These communications, it is broadly agreed, are properly viewed as cases of speech acts. To issue an invoice is (roughly) to request payment for goods received. To issue a receiving report is (roughly) to assert that such-and-such goods have arrived in good condition. To issue a purchase order is (roughly) to request that ownership of certain goods be transferred to the speaker, in consideration of which the speaker promises to pay the current owner a certain amount of money.

It is a handicap to electronic commerce not to have an adequate approach to formalization of speech acts. Our longer-term goal is to replace that deficiency with a productive, well-founded, formal and implementable theory. This note is meant as a step in that direction.

2 Asserting: Two Prototypes

Our purpose in this paper is to demonstrate the coherence, indeed the felicity, of combining Kimbrough's FLBC with Jones's theory of conventional signalling acts. In the interests of ease and clarity of exposition, we will proceed incrementally, and we begin with a discussion of asserting.

[1] E.g., [Kim99], [KM97], [KT00], [Kim01], and [Kim02].
[2] E.g., [Jon02,Jon04,JP04].

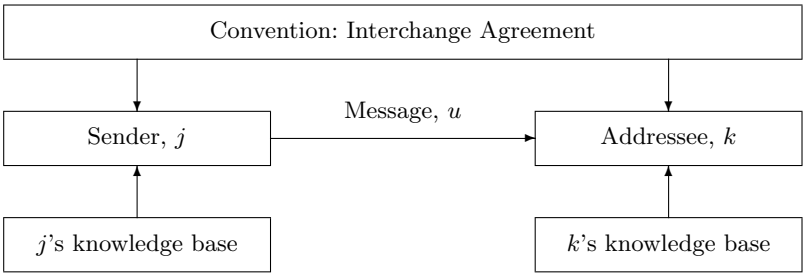

Fig. 1. Basic messaging framework: message u from speaker j to addressee k (after [KT00])

FLBC is a formalism for representing speech act messages. It succeeds to the extent that it affords articulation of speech acts and their contents, and as well as proper inferencing upon them. FLBC is not, and is not intended to be, a formal theory of the logic of speech acts. Instead, it is intended to fit with, to be workable with, a logical theory of speech acts. Jones's account of conventional signalling systems is just such a theory. Put in terms of the Basic Messaging Framework, Figure 1, FLBC is about structuring the messages, u, and Jones's theory of conventional signalling systems belongs to the Interchange Agreement. FLBC is about how we say what we want to say; Jones's theory is about how we may make inferences on what is said.

To an approximation adequate for present purposes, any speech act, and in particular any message u, may be decomposed into an illocutionary force, F, and its propositional content, C. We express them jointly as $F(C)$. The notation is for convenience of exposition; it is a framework and is not part of a logic. That will come shortly.

Jones's core formula in the case of assertion is

Expression 1 (Jones's Assert Schema) $E_j U \Rightarrow_s I_s^* C$

(See [Jon04,JP04].) We have made a change of variables to suit present purposes.) Rendered into English, Expression 1 says that j's seeing to it (E_j) that U counts as making it the case in conventional signalling system s ($\Rightarrow_s$) that were s in an optimal state with respect to its function of facilitating the reliable transmission of reliable information, C would be true. Seeing to it that (E_j), counts as ($\Rightarrow_s$), and ideal functioning (I_s^*) each have their own logics, which we will not discuss in any detail, since they are treated elsewhere.[3] Points arising now:

1. U in Jones's theory may be any (description of a) state of affairs brought about by agent j and falling under the system of conventional signalling, s. U may be the waving of a flag, the shrugging of a shoulder, or whatever

[3] See [Jon04,JP04,JS96].

is stipulated by the convention in force, so long as it is described by the proposition U.
2. The class of signalling conventions in which we are interested here are those that use FLBC expressions to perform U's role.
3. A philosophical point, to which we shall return in comment 4c on Axiom Schema 2, below page 329, is that there is in Expression 1 no requirement of any intention on the part of j, or anyone else. Expression 1 says that—by convention in signalling system s—j's bringing it about that U is a means of stating that C.

FLBC should be seen as (belonging to) a particular convention for undertaking speech acts by machine. According to this convention—let us call it f—one, j, asserts that C to k by sending a message to k of the form:

Expression 2 (FLBC Assert Schema) $\mathit{assert}(e_1) \wedge \mathit{Speaker}(e_1, j) \wedge \mathit{Addressee}(e_1, k) \wedge \mathit{Cul}(e_1, t_1) \wedge \mathit{Content}(e_1, \ulcorner C \urcorner)$

Rendered into English, Expression 2 says that there is an asserting event, e_1, whose speaker is j, and whose propositional content is C. Further, k is to whom the assertion is directed and the assertion event happened (culminated) at time t_1. Note that e_1, j, k, and t_1 are place holders for particular names, i.e., for particular logical constants which are supplied in any given instantiation. Similarly, C is a place holder for a particular formula, to be supplied in any given instantiation. Under f, the *FLBC Speech Act Convention* for communication in a Basic Messaging Framework, j's sending a message, u (see Figure 1), having the form of Expression 2 counts as j's asserting to k that C.

Accompanying Expression 2 in FLBC is an axiom schema formalizing veridicality of an assertion.

Axiom Schema 1 (FLBC Assert Axiom Schema)
$(\mathit{assert}(e) \wedge \mathit{Content}(e, \ulcorner C \urcorner)) \rightarrow (\mathit{Veridical}(e) \leftrightarrow C)$

This belongs to f and is part of the Interchange Agreement.

FLBC and Jones's theory of speech act signalling conventions are now easily combined by adding the following expression to the Interchange Agreement between the communicating parties.

Axiom Schema 2 (Governing Assert Speech Act Axiom Schema)
$E_j(\mathit{assert}(e) \wedge \mathit{Speaker}(e, j) \wedge \mathit{Addressee}(e, k) \wedge \mathit{Cul}(e, t) \wedge \mathit{Content}(e, \ulcorner C \urcorner)) \Rightarrow_f I_f^* C$

Points arising:

1. Axiom Schema 2 is a special case of Expression 1.
2. Axiom Schema 2 should be seen as belonging to the Interchange Agreement. Again, e_1, j, k, and t_1 are place holders for particular names, i.e., for particular logical constants which are supplied in any given instantiation.
3. Successful messaging—utterance of an assert speech act to the effect that C—works as follows under f.
   (a) Parties j and k agree to convention f.
   (b) j sends a message (u in Figure 1) to k, having the form of Expression 2 and using a method of authentication agreed to in f.
   (c) k receives the message, u, validates its authenticity (i.e., that it is indeed from j), and (under an obligation stipulated by f) concludes that $E_j u$. Further, by the logic of seeing to it that (of which more below), k also concludes that u.
   (d) From $E_j u$ and Axiom Schema 2, k is also licensed to conclude that $I_f^* C$.
4. There are a number of ways in which messaging in this context may be unsuccessful or infelicitous in some way. These include the following:
   (a) The message u could be ill-formed with regard to f.
   Messages in FLBC are fully formal and can be exactly specified. These specifications should belong to f, as well as rules for handling violations. An advantage of logicism and full formalization here is that acceptance or rejection of messages can be specified rigorously and automated.
   (b) The content asserted by the speaker, C, might not be believed by the speaker, who may know that its denial is true.
   People lie and no logical system will, or should, prevent that. If $\neg C$, then it will follow from Axiom Schema 1 and the truth of its antecedent that $\neg V(e_1)$, where e_1 is the message ID of j's original utterance.
   (c) The speaker, j, may disavow the assertion.
   The authentication system in place, which must be part of the governing convention, is crucial. If it is easily defeated, the signalling system is unlikely to be successful for very long. If the authentication system is reliable, there remains the problem of distinguishing accidental utterances from fraudulent attempts to renege. The default assumption is that if an f-message is transmitted, the act of transmission counts as an instance of implementation of the governing signalling convention, and so *means what*—according to that convention—*it says.* If the sender (or its owner) wishes to maintain that the transmission was made in error, then the onus of proof will be on the sender or owner to show just that. (Perhaps the governing legal system, or some other relevant authority, will be the adjudicator of last resort on the

issue of distinguishing between errors and genuine signalling acts.) In the case of human signallers, some speech-act theorists would appeal, at this point, to *intention,* to sort the act-tokens that count as literal implementation of a governing signalling convention from those that do not so count. But the view taken in this paper is that there is here no *need* to resort to intention. A good thing this, in the context of e-commerce, since it is very unclear what ascription of intentions to electronic agents amounts to; and equally obscure, therefore, is the issue of how to specify the empirical conditions that would have to be satisfied before an electronic agent could be said to *have* a particular intention. But communicate they can, these electronic agents, for they can perform acts which—according to the governing interchange agreement—have a meaning.

(d) Disputes arise because messages are ambiguous.
This is always a possibility, as is resolution by adjudication. That said, it must also be admitted that it would be difficult to find a more transparent and clear form of formalization than logic as on display here. The *prima facie* case for clarity is strong.

Following a valid assert message (whether felicitous or not), the recipient, k, is in a good position to make automated inferences of import, depending of course on the actual course of events. As noted by Jones for example,[4] our present expressions may be combined with a belief operator B_j (j believes that) to articulate various *positions* of belief and trust. Again, in the interests of brevity, we refer the reader to the original discussions [Jon02,Jon04,JP04].

3 Other Speech Acts

While there are an indefinitely large number of distinct speech act types, most authors recognize a core group that includes assertions, commissives, requests, and declaratives. We will limit our discussion largely to these. The pattern we saw in the case of asserting persists, and will (we believe) persist for other types of speech acts.

3.1 Commands & Requests

Expression 3 (Jones's Command Schema) $E_jU \Rightarrow_s I_s^* O E_k C$

In stylized English, if U counts as a command (by j to k), then in all circumstances in which the conventional signalling system, s, is working ideally (I_s^*), it is obligatory (O) that k sees to it (E_k) that C. The thought is that it is constitutive of the concept of a command that, if given felicitously, there is an obligation created for the one commanded to do what was commanded.

[4] [Jon02,Jon04,JP04]

Jones's theory views requests as weaker than, or at least as somewhat different from, commands.

Expression 4 (Jones's Request Schema) $E_jU \Rightarrow_s I_s^* H_j E_k C$

In English, the upshot of a felicitous request is that the requester, j, attempts to see to it (H_j) that k sees to it that C.

FLBC has historically taken the view that both commands and requests (in Jones's sense) are varieties of the covering speech act, request, and are characterized by being honored or not, just as assertions are either veridical or not. In FLBC, then, we have:

Expression 5 (FLBC Command Schema) $command(e_1) \wedge Speaker(e_1, j) \wedge Addressee(e_1, k) \wedge Cul(e_1, t_1) \wedge Content(e_1, \lceil C \rceil)$

and

Expression 6 (FLBC Request Schema) $request(e_1) \wedge Speaker(e_1, j) \wedge Addressee(e_1, k) \wedge Cul(e_1, t_1) \wedge Content(e_1, \lceil C \rceil)$

along with

Axiom Schema 3 (FLBC Request Axiom Schema) $(request(e) \wedge Content(e, \lceil C \rceil)) \rightarrow (Honored(e) \leftrightarrow C)$

and

Axiom Schema 4 (FLBC Command Axiom Schema) $(command(e) \wedge Content(e, \lceil C \rceil)) \rightarrow (Honored(e) \leftrightarrow C)$

Following the pattern in the case of asserting, this leads directly to:

Axiom Schema 5 (Governing Command Axiom Schema) $E_j(command(e) \wedge Speaker(e, j) \wedge Addressee(e, k) \wedge Cul(e, t) \wedge Content(e, \lceil C \rceil)) \Rightarrow_f I_f^* O E_k C$

and

Axiom Schema 6 (Governing Request Axiom Schema) $E_j(request(e) \wedge Speaker(e, j) \wedge Addressee(e, k) \wedge Cul(e, t) \wedge Content(e, \lceil C \rceil)) \Rightarrow_f I_f^* H_j E_k C$

Points arising:

1. If, as in Jones's view, commands are rather different from requests, grouping them together as acts that may or may not be honored, as in the FLBC schemata above, may not be appropriate; finer distinctions may be called for.

2. Obligations may themselves be relativized to institutions. Contrast, for example, a command from a policeman and a command from an arbiter of social etiquette. Thus, finer distinctions may be appropriate for the analysis of commands. We note that the counts as operator ($\Rightarrow_s$) is indexed by institution as is the ideality operator (I^*_s). These indices might also be used for relativizing obligations to institutions.
3. As for requests, one way of attempting to see to it that someone does something is to place that person under an obligation to do so.
4. The upshot here is that while different analyses are certainly possible the associated logical apparatus is quite flexible and will support a broad range of views.

3.2 Commissives

Promises and other kinds of commissives have the function, in Jones's analysis, of placing the speaker under an obligation to see to it that what was promised (or committed to) comes about.

Expression 7 (Jones's Commissive Schema) $E_jU \Rightarrow_s I^*_s OE_jC$

In FLBC we have

Expression 8 (FLBC Commit Schema) $\mathit{commit}(e_1) \wedge \mathit{Speaker}(e_1, j) \wedge \mathit{Addressee}(e_1, k) \wedge \mathit{Cul}(e_1, t_1) \wedge \mathit{Content}(e_1, \lceil C \rceil)$

along with

Axiom Schema 7 (FLBC Commit Axiom Schema) $(\mathit{commit}(e) \wedge \mathit{Content}(e, \lceil C \rceil)) \rightarrow (\mathit{Kept}(e) \leftrightarrow C)$

In FLBC, promises (and commissives generally) are characterized by whether they are kept or not. Jones's analysis undertakes to represent the deontic consequences of making a promise and in general of giving a commitment.

The usual pattern applies when the two perspectives are integrated.

Axiom Schema 8 (Governing Commissive Axiom Schema) $E_j(\mathit{commit}(e) \wedge \mathit{Speaker}(e, j) \wedge \mathit{Addressee}(e, k) \wedge \mathit{Cul}(e, t) \wedge \mathit{Content}(e, \lceil C \rceil)) \Rightarrow_f I^*_f OE_jC$

Points arising:

1. As noted above, there may be need for a more resolved view of obligation. Different institutions may require different commitments, so obligations may need to be relativized to institutions.
2. For some purposes a more detailed modeling may be appropriate. For example, promises are usually seen as applying only to the future. A promise to do something in the past is infelicitous. Such constraints can be added to the formalism we introduce. We leave the details for future work. In many practical situations, however, these kinds of refinements may not be necessary.

3.3 Declaratives

A declarative signalling act (in ideal or felicitous conditions) brings about the state of affairs described by its content. Sometimes saying so indeed makes it so. A state of war may be brought about by declaring it to be the case. Similarly, naming (by parents or other authorities) and pronouncing (by juries, judges, clerics, and referees) are acts that will typically bring about the conditions described by their contents.

Jones's analysis, and the corresponding FLBC representations, follow the usual patterns.

Expression 9 (Jones's Declarative Schema) $E_jU \Rightarrow_s I_s^* E_j C$

Under Jones's analysis j's bringing about the utterance U counts, under ideal circumstances, as j's bringing about the state of affairs described by C. In FLBC we have

Expression 10 (FLBC Declaration Schema) $\mathit{declare}(e_1) \wedge \mathit{Speaker}(e_1, j) \wedge \mathit{Addressee}(e_1, k) \wedge \mathit{Cul}(e_1, t_1) \wedge \mathit{Content}(e_1, \lceil C \rceil)$

along with

Axiom Schema 9 (FLBC Declaration Axiom Schema) $(\mathit{declare}(e) \wedge \mathit{Content}(e, \lceil C \rceil)) \rightarrow (\mathit{Authoritative}(e) \rightarrow C)$

Again, the usual pattern applies when the two perspectives are integrated.

Axiom Schema 10 (Governing Declarative Axiom Schema) $E_j(\mathit{declare}(e) \wedge \mathit{Speaker}(e, j) \wedge \mathit{Addressee}(e, k) \wedge \mathit{Cul}(e, t) \wedge \mathit{Content}(e, \lceil C \rceil)) \Rightarrow_f I_f^* E_j C$

Regarding the FLBC axiom schema, the special predicate *Authoritative* must be interpreted carefully. In a sporting event, such as baseball, an umpire may declare a player out. Which umpire has the authority to do so depends upon the state of play, and so an umpire may say a player is out but lack the proper authority and in fact be overruled by another umpire. But there is nothing in principle to prevent two umpires, one lacking authority, *both* to declare a player out. Consequently, saying without authority that a player is out is *not* sufficient for the player to be safe (not out). The usual biconditional has to be replaced by the weaker conditional.[5]

[5] In fact each of the FLBC speech act auxiliaries—*Kept, Honored, Authoritative, Veridical*—merit careful discussion and interpretation. That, however, is beyond the scope of this paper. We note, however, that the event indices in FLBC, e_1, e_2, etc., may be exploited to mark the cause of a truth. C may be true *by virtue of* e_2 but not true by virtue of e_3.

4 Discussion: Towards Deployment

The logical analysis of signalling acts will, we hope, contribute to electronic commerce in each of the three ways identified in the Introduction: as a means of clarification, as a guide to design, and as a basis for implementation. To that end we offer the following remarks, more to spur discussion than to complete it.

4.1 Clarification: Intentions and Speech Acts

Speech act theory is not without contending schools of thought. Here we wish to comment briefly on the debate between the intentionist and conventionist views regarding the proper analysis of speech acts. Despite his criticisms of the Gricean intention-based theory of meaning [Gri57], Searle will for present purposes be taken to be one of the many representatives of the intentionist theory.[6] See also many of the papers in [CMP90] and much of the computer science literature, e.g., [Sin93,SC96], plus KQML[7] and other agent communication languages. The following passage from Searle is representative of intentionist theory for speech acts as we shall discuss it here.

> So far we have considered only the case of a sincere promise. But insincere promises are promises nonetheless, and we now need to show how to modify the conditions to allow for them. In making an insincere promise the speaker does not have all the intentions he has when making a sincere promise; in particular he lacks the intention to perform the act promised. However, he purports to have that intention. Indeed, it is because he purports to have intentions which he does not have that we describe his act as insincere.
> A promise involves an expression of intention, whether sincere or insincere. So to allow for insincere promises, we need only to revise our conditions to state that the speaker takes responsibility for having the intention rather than stating that he actually has it. A clue that the speaker does take such responsibility is the fact that he could not say without absurdity, e.g., "I promise to do A but I do not intend to do A". To say, "I promise to do A" is to take responsibility for intending to do A, and this condition holds whether the utterance was sincere or insincere. To allow for the possibility of an insincere promise, then we have only to revise condition 6 so that it states not that the speaker intends to do A, but that he takes responsibility for intending to do A, ... [Sea69, page 62]

[6] Bach and Harnish [BH79] adopt a strong intentionist view of speech acts and communication. They see Searle as holding a conventionist view in contrast to their intention-and-inference theory. These are issues beyond the scope of this paper.

[7] E.g., [Cov98], [FFMM94a], [FFMM94b], [FW$^+$93], [LF94], [MLF96], and [Moo00a]. See for KQML: http://www.cs.umbc.edu/kqml/.

Searle's claim that "it is because he purports to have intentions which he does not have that we describe his act as insincere" is not an argument for his intentionist position so much as a restatement of it. Falsely purporting is of course a reason for attributing insincerity. So, according to a conventionist, would be invoking a convention without intending to meet the obligations that come with it. By performing a signalling act of the commissive type, the agent places himself under an obligation (to do A). There is nothing *absurd* in his saying, additionally, that he does not intend to do A, although it might be unwise for him to explicitly reveal his insincerity in this way. Insincerity can be incorporated without recourse to a change in the way promising itself is understood. In particular, there is no need to resort to a revised condition of the type proposed by Searle—unless of course we are to understand 'taking responsibility for intending to do A' as merely a roundabout way of saying 'placing oneself under an obligation to do A'.

The core of the conventionist view is that communicative acts occur in the context of governing conventions. These conventions stipulate the states of affairs that should obtain in consequence of performance of the communicative acts themselves. Under Jones's analysis of the convention of committing, Expression 7, if j performs a signalling act that counts in s as a commissive (with respect to C), then j is placed under an obligation to see to it that C, unless certain ideality conditions are not met. What conditions are these? Well, in particular, j will have to be an agent who is empowered to place himself under an obligation. Among human agents, a minor, for instance, might not be so empowered. Among electronic agents, the institutional arrangement might be that only certain categories of agent are so empowered.

To this the intentionist might perhaps respond: whether or not j's performance of the given signalling act does indeed count as a commissive will depend on the intentions j has when he performs the act. For suppose he sends the signal by accident, or is play-acting, or just joking, would we then say that he has placed himself under an obligation? But here we are back to the issue addressed above in point 4c, page 329, pertaining to Axiom Schema 2. If the communicating agent, or its owner, wishes to maintain that the communicative act was not *serious*, not a *literal* implementation of the governing convention, then the onus of proof will be on the sender or owner to show just why it was not.

4.2 Design and Implementation

Kimbrough's FLBC was designed with an eye to implementation. The formulation in first-order logic, even with quotation, lends itself well to logic programming formalisms. This facilitates implementation either in a logic programming environment or in more conventional programming system.[8] Combining FLBC with Jones's analysis of signalling conventions, however,

[8] See the work of Alan Abrahams in this regard, e.g., [Abr02,AEB04].

introduces several new sentence operators, each with its own logic, notably I^*, E_j, and O. We shall now present an example that illustrates how our integration of FLBC and Jones's analysis of signalling conventions might be implemented in a logic programming formalism. Our purpose is merely to sketch a plausibility case. The full case requires a lengthy and detailed treatment, which is beyond the scope of this, or any single, paper.

Consider as an example of a content sentence, C:

Expression 11 *Andrea Doria leaves Boston on January 1, 2005.*

Here is an FLBC representation:

Expression 12 *leave*(*e1*) ∧ *Experiencer*(*e1, Andrea Doria*) ∧ *Goal*(*e1, Boston*) ∧ *Cul*(*e1, 20050101*)

Note that *e1* is (in virtue of the covering interchange agreement) a unique ID for Expression 12. Also, *Cul* is a special predicate indicating the time of an event, here *e1*. Converting Expression 12 to a Prolog representation in which the expression is the quoted part of a *Content* predicate gives us Expression 13.

Expression 13
```
content(e2, (leave(e1),
experiencer(e1, 'Andrea Doria'),
goal(e1, 'Boston'), cul(e1, '20050101'))).
```

Suppose now that Bob promises Carol that Andrea Doria leaves Boston on January 1, 2005. In FLBC:

Expression 14 *promise*(*e2*) ∧ *Speaker*(*e2, 'Bob'*) ∧ *Addressee*(*e1, 'Carol'*) ∧ *Content*(*e2,*⌈*leave*(*e1*) ∧ *Experiencer*(*e1, 'Andrea Doria'*) ∧ *Goal*(*e1, Boston*) ∧ *Cul*(*e1, 20050101*)⌉) ∧ *Cul*(*e2, 20041201*)

In Prolog, a message/2 clause:

Expression 15 (Utterance Example in Prolog)
```
message(e2, (promise(e2),
speaker(e2, 'Bob'), addressee(e2, 'Carol'),
content(e2, (leave(e1) , experiencer(e1,
'Andrea Doria') , goal(e1, 'Boston'),
cul(e1, 20050101))) , cul(e2, 20041201))).
```

At this point we make contact with Jones's analysis of signalling conventions. We need a Prolog representation of

Axiom Schema 11 (Governing Promising Axiom Schema)
$E_j(promise(e) \wedge Speaker(e, j) \wedge Addressee(e, k) \wedge Cul(e, t) \wedge Content(e, \lceil C \rceil)) \Rightarrow_f I_f^* O E_j C$

Our representation will be approximate, and in two parts. First, $\Rightarrow_f$, the 'counts as' connective in Axiom Schema 11, also the main connective in the expression, will be represented by a Prolog predicate of arity 2, `countsas`:

Expression 16 (Promising Axiom Schema in Prolog)

```
countsas(istar(obligation(
(stit(E),agent(E,S),content(E,C)))),
message(E,(promise(E),speaker(E,S),
addressee(E,A),content(E,C),cul(E,T)))).
```

Note that the first argument,

```
istar(obligation(stit(E,C))),
```

corresponds to the right-hand side of Axiom Schema 11, and the second argument is the schema for a `message` (see Expression 15). `E`, `A`, `C` and `T` are free variables (subject to uniform substitution), permitting Expression 16 to act as a general rule, or axiom schema. If we are to deduce much from Expression 16 we need a second part for our representation. There are a number of ways to achieve this, but perhaps the simplest is to add a general rule that supports a form of detachment based on Expression 16. We can do this in Prolog with Expression 17.

Expression 17 (Promising Rule Schema in Prolog)

```
istar(obligation(
(stit(E),agent(E,S),content(E,C)))) :-
countsas(istar(
obligation((stit(E),agent(E,S),
content(E,C)))),
message(E,(promise(E),speaker(E,S),
addressee(E,A), content(E,C),cul(E,T)))),
message(E,(promise(E),speaker(E,S),
addressee(E,A),content(E,C),cul(E,T))).
```

Taken together, Expressions 15, 16 and 17 support a deduction in Prolog that, in ideal circumstances, there is an obligation that Bob sees to it that there is a leaving by Andrea Doria for Boston on January 1, 2005.

```
?- istar(X).

X = obligation((stit(e2), agent(e2, 'Bob'),
content(e2, (leave(e1),
experiencer(e1, 'Andrea Doria'),
goal(e1, 'Boston'),
cul(e1, 20050101)))))
```

Adding new messages having the form of Expression 15 will allow additional such deductions to be made.

The illustration just given of an implementation in Prolog is very much an approximation and obviously requires much to be completed. Even so, it suits our present purpose, which is to further the plausibility of a thoroughgoing logicist approach to the Basic Messaging Framework, Figure 1. In furtherance of that end, we conclude this section with a discussion of how the *stit* (sees to it that) operator, E_j, can be articulated in FLBC. The Prolog exercise just concluded should be sufficient to show that a subsequent translation from FLBC to logic programming may be made straightforwardly. We acknowledge this as a promissory note and add to the list detailed articulation of the countsas operator ($\Rightarrow_s$), the I-star operator (I_s^*), and the deontic operators, including that for obligation O.

4.3 *stit* in FLBC

From action logic, E_jA, or 'j sees to it that A', is rendered into FLBC as:

Expression 18 (FLBC Stit Schema) $stit(e_1) \wedge Agent(e_1, j) \wedge Cul(e_1, t_1) \wedge Content(e_1, \lceil A \rceil)$

Action logic introduces a second operator, C_j, called *capacitation.* C_jA may be interpreted as 'j has the capacity (or ability) to produce the state of affairs described by A'. This is represented in FLBC as:

Expression 19 (FLBC Capacitation Schema) $capacitation(e_1) \wedge Agent(e_1, j) \wedge Hold(e_1, t_1) \wedge Content(e_1, \lceil A \rceil)$

(Rough translation: e_1 is a particular capacitation state; j is an agent in that state; e_1 has content $\lceil A \rceil$, and the state obtains, or holds, at time t_1. Note that events are said to happen or culminate (*Cul*) at a given time, and states are said to obtain or hold (*Hold*) at a given time. See Parsons [Par90] for exposition on this distinction.)

We assume a standard version of action logic, as presented in [Jon04], which is characterized by a series of axiom schemas or rules of inference. We need FLBC analogs to them. In the original logic seven principles apply. The first is:

$$\text{If} \vdash A \leftrightarrow B \text{ then} \vdash E_jA \leftrightarrow E_jB \tag{1}$$

Translation: If A and B are logically equivalent, infer that E_jA and E_jB are logically equivalent. The analog for *stit* is

Expression 20 If $\vdash A \leftrightarrow B$ then
$\vdash stit(e) \wedge Agent(e, i) \wedge Content(e, \lceil A \rceil) \leftrightarrow$
$stit(e) \wedge Agent(e, i) \wedge Content(e, \lceil B \rceil)$

A corresponding rule of inference applies to C_j:

$$\text{If} \vdash A \leftrightarrow B \text{ then} \vdash C_jA \leftrightarrow C_jB \tag{2}$$

Its FLBC translation is:

Expression 21 If $\vdash A \leftrightarrow B$ then $\vdash$ *capacitation*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil A \rceil) \leftrightarrow$ *capacitation*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil B \rceil)$

The five remaining principles are axiom schemas in the original action logic.

$$E_i A \rightarrow A \tag{3}$$

In FLBC:

Expression 22 *stit*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil A \rceil) \rightarrow A$

$$(E_i A \wedge E_i B) \rightarrow E_i (A \wedge B) \tag{4}$$

In FLBC:

Expression 23 (*stit*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil A \rceil) \wedge$ *stit*$(e') \wedge$ *Agent*$(e', i) \wedge$ *Content*$(e', \lceil B \rceil)) \rightarrow$ *stit*$([e, e']) \wedge$ *Agent*$([e, e'], i) \wedge$ *Content*$([e, e'], \lceil A \wedge B \rceil)$

$$\neg E_i \top \tag{5}$$

Similarly for C_i:

$$\neg C_i \top \tag{6}$$

In FLBC we add rules of inference:

Expression 24 (E_i Rule) If $\vdash A \leftrightarrow \top$ then $\vdash \neg$(*stit*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil A \rceil))$

Expression 25 (C_i Rule) If $\vdash A \leftrightarrow \top$ then $\vdash \neg$(*capacitation*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil A \rceil))$

Finally:

$$E_i A \rightarrow C_i A \tag{7}$$

In FLBC:

Expression 26 *stit*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil A \rceil) \rightarrow$ *capacitation*$(e) \wedge$ *Agent*$(e, i) \wedge$ *Content*$(e, \lceil A \rceil)$

5 Summary and Conclusion

The Basic Messaging Framework, Figure 1, describes the communication setup for electronic commerce. In that framework the Interchange Agreement plays a large and essential role. The Interchange Agreement is, at bottom, a conceptual abstraction that covers the conventions needed to conduct business transactions. Consequently, seeing speech acts as events in a conventional signalling system fits naturally with the Basic Messaging Framework: the underlying speech act conventions are simply part of the Interchange

Agreement. Formalizing any of the conventions in the Interchange Agreement has the salutary prospect of clarifying concepts, of guiding design, and even of supporting implementation.

We have essayed in this paper a demonstration of how speech act conventions as formalized by Jones's work may be made to fit with Kimbrough's FLBC formalization of messages. The project is far from complete. There are many technical and conceptual alternatives that merit investigation, and scaled-up implementation will be required to test fully these ideas. Our goal here has been the modest one of presenting necessary components for a thorough formal modeling of communicative acts in the context of electronic commerce. Speech acts are among the most important of these components, as is their attending inferential apparatus. A philosophically sound formalization of speech acts has been unified with an expressively powerful message representation formalism, and a sketch has been made of how the combined result could be rather directly representable in Prolog. Very much remains to be done to redeem the promissory notes issued. Even so, this is, we submit, a strong and favorable indicator for the near-term prospects of a strong logicism in electronic commerce.

References

[Abr02] Alan S. Abrahams, *Developing and executing electronic commerce applications with occurrences*, Ph.D. thesis, University of Cambridge Computer Laboratory, 2002.

[AEB04] Alan S. Abrahams, David M. Eyers, and Jean M. Bacon, *Practical contract storage, checking, and enforcement for business process automation*, Formal Modelling for Electronic Commerce: Representation, Inference, and Strategic Interaction (Steven O. Kimbrough and D. J. Wu, eds.), Springer, Berlin, Germany, 2004.

[Aus62] John L. Austin, *How to do things with words*, Oxford at the Clarendon Press, Oxford, England, 1962.

[BH79] Kent Bach and Robert M. Harnish, *Linguistic communication and speech acts*, The MIT Press, Cambridge, Massachusetts, 1979.

[CMP90] Philip R. Cohen, Jerry Morgan, and Martha E. Pollack (eds.), *Intentions in communication*, System Development Foundation Benchmark, The MIT Press, Cambridge, Massachusetts, 1990.

[Cov98] Michael A. Covington, *Speech acts, electronic commerce, and KQML*, Decision Support Systems **22** (1998), no. 3, 203–211.

[FFMM94a] Tim Finin, Richard Fritzson, Don McKay, and Robin McEntire, *KQML as an agent communication language*, Proceedings of the Third International Conference on Information and Knowledge Management (CIKM '94), ACM Press, November 1994.

[FFMM94b] ———, *KQML as an agent communication language*, The Proceedings of the Third International Conference on Information and Knowledge Management (CIKM '94), ACM, ACM Press, November 1994.

[FW+93] Tim Finin, Jay Weber, et al., *Draft specification of the KQML agent–communication language plus example agent policies and architectures*, Manuscript obtained from `http://www.cs.umbc.edu`, 1993.

[Gri57] Paul Grice, *Studies in the way of words*, ch. Meaning, pp. 213–223, Harvard University Press, Cambridge, MA, 1989 (originally 1957), .

[HS98] Michael N. Huhns and Munindar P. Singh (eds.), *Readings in agents*, Morgan Kaufmann, San Francisco, CA, 1998, ISBN: 1-55860-495-2.

[Jon02] Andrew J.I. Jones, *On the concept of trust*, Decision Support Systems **33** (2002), no. 3, 225–232.

[Jon04] ———, *A logical framework*, Open Agent Societies: Normative Specifications in Multi-Agent Systems (Jeremy Pitt, ed.), John Wiley & Sons, Chichester, UK, 30 December 2004, ISBN: 047148668X.

[JP04] Andrew J.I. Jones and X. Parent, *Conventional signalling acts and conversation*, Advances in Agent Communication (Frank Dignum, ed.), Lecture Notes in Artificial Intelligence, Volumn 2922, Springer-Verlag, Berlin, Heidelberg, New York, 2004, pp. 1–17.

[JS96] Andrew J.I. Jones and Marek J. Sergot, *A formal characterisation of institutionalised power*, Journal of the Interest Group in Pure and Applied Logic (IGPL) **4** (1996), no. 3, 427–443, Reprinted in [V+97, pages 349–367].

[Kim99] Steven O. Kimbrough, *Formal language for business communication: Sketch of a basic theory*, International Journal of Electronic Commerce **3** (Winter 1998–99), no. 2, 23–44.

[Kim01] ———, *Reasoning about the objects of attitudes and operators: Towards a disquotation theory for representation of propositional content*, Proceedings of ICAIL '01, International Conference on Artificial Intelligence and Law, 2001.

[Kim02] ———, *A note on the Good Samaritan paradox and the disquotation theory of propositional content*, Proceedings of ΔEON'02, Sixth International Workshop on Deontic Logic in Computer Science (John Horty and Andrew J.I. Jones, eds.), May 2002, pp. 139–148.

[KM97] Steven O. Kimbrough and Scott A. Moore, *On automated message processing in electronic commerce and work support systems: Speech act theory and expressive felicity*, ACM Transactions on Information Systems **15** (October 1997), no. 4, 321–367.

[KT00] Steven O. Kimbrough and Yao-Hua Tan, *On lean messaging with unfolding and unwrapping for electronic commerce*, International Journal of Electronic Commerce **5** (2000), no. 1, 83–108.

[LF94] Yannis Labrou and Tim Finin, *A semantics approach for KQML—a general purpose communication language for software agents*, Third International Conference on Information and Knowledge Management (CIKM '94), November 1994.

[MLF96] James Mayfield, Yannis Labrou, and Tim Finin, *Evaluation of KQML as an agent communication language*, Intelligent Agents Volume II – Proceedings of the 1995 Workshop on Agent Theories, Architectures, and Languages (Berlin, Germany) (M. Wooldridge, J. P. Muller, and M. Tambe, eds.), Springer-Verlag, 1996.

[Moo00] Scott A. Moore, *KQML and FLBC: Contrasting agent communication languages*, International Journal of Electronic Commerce **5** (2000), no. 1, 109–124.

[Par90] Terence Parsons, *Events in the semantics of English: A study in subatomic semantics*, Current Studies in Linguistics, The MIT Press, Cambridge, MA, 1990, ISBN: 0-262-66093-8.

[SC96] Ira A. Smith and Philip R. Cohen, *Toward a semantics for an agent communication language based on speech acts*, Proceedings of the Thirteenth National Conference on Artificial Intelligence and the Eighth Innovative Applications of Artificial Intelligence Conference, Vol. 2 (Menlo Park, California) (Howard Shrobe and Ted Senator, eds.), AAAI Press, 1996, pp. 24–31.

[Sea69] John R. Searle, *Speech acts*, Cambridge University Press, Cambridge, England, 1969.

[Sin93] Munidar P. Singh, *A semantics for speech acts*, Annals of Mathematics and Artificial Intelligence **8** (1993), no. I–II, 47–71, Reprinted in [HS98].

[V+97] E. Garzòn Valdés et al. (eds.), *Normative systems in legal and moral theory – festschrift for Carlos E. Alchourrón and Eugenio Bulygin*, Duncker & Humblot, Berlin, Germany, 1997.