Formal Aspects of Electronic Commerce: Research Issues and Challenges

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ABSTRACT: The notion of electronic or digital commerce is gaining widespread popularity. For the most part, these developments are being led by industry and government, with academic research following these trends in the form of empirical and economic research. Much more fundamental improvements to (global) commerce are possible but are presently being overlooked for lack of adequate formal theories, representations, and tools. This paper attempts to incite research in these directions.

KEY WORDS AND PHRASES: deontic reasoning, electronic commerce, formal methods, linguistic methods, Open EDI, speech act theory.

"Fish gotta swim, birds gotta fly."1 Producers gotta sell, consumers gotta buy. Commerce is the art of bringing this about; it is the art of making buying and selling go well. Electronic, or digital, commerce (EC or DC) is the use of telematics-based systems (computer and communications systems) to support the conduct of commerce.2 The enticing prospect of electronic commerce is the likelihood (widely regarded as genuine) of using telematics greatly to advance the art of making the conduct of commerce go well. With computer and communication systems, it is hoped, the conduct of commerce may become better (e.g., of higher quality, of improved manageability, of broader scope, of greater scale), faster, and cheaper.

But the prospects are before us and such hopes are not yet fully realized. One might be content to watch the developments and speculate, or—as is our motivation—one might wish to contribute to the application of computer and communications technology to the support of commerce. In either case, at least four key questions arise:

1. What is possible (and desirable) with electronic commerce? What new services, features, and functionality will be possible with electronic commerce? We call this the possibilities question. What the possibilities are is far from obvious. Moreover, the field of telematics has a long history of surprising and innovative ideas and applications whose consequences are far-reaching and typically unintended. The Internet and the World Wide Web are recent and obvious examples that present features and functionality that arrived suddenly and were largely surprising.

2. What are the operational and functional requirements for applications in digital commerce? If, for example, it is possible and desirable to have electronic markets, then surely we will need secure, authenticated, easy-to-use payment mechanisms, and we will need effective, attractive user interfaces. What else? We call this the requirements question.

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3. **How should what is possible be made actual?** If, for example, electronic markets are to become widespread, how should this be done? How can secure, authenticated, payment mechanisms be designed and delivered? How should information be presented and organized for effective user interfaces in electronic shopping? We call this the technology and design question.

4. **What will widespread realization of the possibilities for electronic commerce mean?** How will productivity be enhanced and industrial organization be affected? This is the interpretation question.

No single paper, or even a single book, could do full justice to any one of these questions. Yet, in what follows, we have something, if only a little, to say about each. What we have to say here is rather focused, following a linguistic and formal perspective, as we shall explain. We focus on work from Wharton and EURIDIS. (There is other, good and relevant, work, but the limitation we impose makes for a coherent story and helps us avoid the halting problem.) The paper proceeds in a discursive fashion, listing and taking up various topics by turn that are associated with our limited aims. We will return to these four questions at the end and offer some integrative remarks.

**A Linguistic Perspective: Formalization**

This paper is based on what might be called a linguistic perspective on electronic commerce. We view the situation in electronic commerce today as somewhat analogous to the challenge of early seafaring traders in the times of the European discoveries of trade routes to Africa, Asia, and the New World. Like globe-surfing on the Web today, those traders entered many new and strange ports where the languages and the ways of doing business were totally unfamiliar.

In those days, the solution to the language problem took the form of a *lingua franca* (e.g., a simplified variant of Portuguese) that trading partners of different nationalities used as a canonical dialect for doing business.

Various standardized solutions were also sought for the problem of differing trade practices in the form of trade conventions and guidelines. These have had to be continually revised for advances in communication technologies, transport technologies, and financing mechanisms.

Our new trade routes today are digital; instead of boats, we have computational agents. Our *lingua franca* (mainly EDI, but also think of HTTP, FTP) is still rather crude. Likewise, there are still very few guidelines and conventions for electronic commerce trading practices. Finally, our traders will not be brave sailors, but intelligent artificial agents who know how to speak the *lingua franca* of electronic commerce, who understand the relevant trading practices, and who are able to act in our interests with great effectiveness and autonomy.

All of this requires careful formalization. What the agents (or processes) say to one another must be expressed in a formalized language for business
communication of some variety. If the agents are to understand and make use of guidelines and conventions for trading practices, then these guidelines and conventions must be modeled and expressed formally. Finally, if the agents are to reason their way to useful actions, this, too, requires formalization, here of rules and principles for negotiation and decision.

**Formalized Messaging for Digital Commerce**

**Motivation: Limitation of the EDI Approach**

To the extent that there is a currently available *lingua franca* for electronic commerce, it is electronic data interchange, or EDI. EDI is “the movement of business documents electronically between or within firms (including their agents or intermediaries) in a structured, machine retrievable data format that permits data to be transferred, without rekeying, from a business application in one location to a business application in another location” [13, 49]. Instead of exchanging purchase orders and invoices as paper documents, EDI trading partners transmit standardized electronic versions of these documents from the originator’s computer directly to the receiver’s computer. In the United States, standards have been developed by the American National Standards Institute (ANSI) task group X12 [1]. On the international level, the United Nations and the Economic Commission of Europe are working to develop a coordinated international standard, called EDIFACT (Electronic Data Interchange for Administration, Commerce and Transport; see [17, 18]). EDI systems have been extensively and successfully implemented, often involving multiple business functions (e.g., shipping and billing), multiple industries (e.g., railroads and insurance), and, in the case of the EDIFACT standards, multiple countries.

Despite this apparent success, many hold that the existing EDI messaging standards (e.g., EDI X12, UN/EDIFACT) are cumbersome and inflexible, and highly circumscribed in what they can express. Because of this, an overemphasis on conforming to the EDI messaging standards is hampering more imaginative development of electronic commerce.³ This raises the question: What would a messaging formalism look like that is (a) flexible, (b) highly expressive, (c) computable, and (d) maintainable?

For such reasons, the idea of developing formal languages for business communication (FLBCs) has been bruited about [22, 35]. The notion underlying the FLBC concept is to have a formal language, with a (recursive) syntax and semantics, for conducting business communications that is much more powerful and general than those, such as X12 and EDIFACT, now used for digital commerce. The hope is that a well-designed FLBC will have the flexibility and openness needed to accommodate changes and nuanced differences among applications, and that all the while it will be able to express what needs to be said. (For more on FLBCs, see [6, 20, 24, 25, 26, 36].)

How should a sufficiently general and powerful FLBC be designed? In particular, what should its logical structure be? We want to emphasize that this is *not* a question about designing a proper syntax for an FLBC. That is a
relatively trivial problem, akin to deciding whether to write arithmetic operators in infix, prefix, or postfix format. Rather, the question probes deeper and should be interpreted as asking what a proper formalism would denote. Retaining the analogy, we ask, “What are the arithmetic operators, and what are their properties?,” not “What symbols should we use to represent the operators and how should we order their presentation?”

**Challenge: Logical Requirements for FLBC**

The main area of research in formal messaging for electronic commerce is on logical operators for FLBC (including speech act operators; see below). The logical operators that have drawn the most attention in the literature and in the oral tradition are modal operators (for possibility and necessity), temporal operators (for reasoning about time), deontic operators (for reasoning about obligations and permissions), and defeasibility operators (for reasoning defeasibly or nonmonotonically [24]). Modal and temporal operators have long been investigated in logic, philosophy, and computer science. Research in FLBC and electronic commerce has sought to incorporate prior results and to think through the interactions of multiple types of operators.

We should note that, at present, the extent to which nonstandard logics need representation in electronic commerce messages is not clear, as opposed to the message interpretation and generation procedures. This may be called the what-is-said versus what-is-inferred issue. Clearly, for example, we need to have messages that say “We promise that . . .” But promising creates an obligation, at least defeasibly. Do we also need messages to say, “In light of our promise that —, we are defeasibly obligated to bring it about that . . .”? One might think this should be inferred. The issue at large remains very much open. However it turns out, research on the underlying logics and their application to electronic commerce should be invaluable. As with much else in information systems, progress consists in no small part in structuring a domain so that it may be effectively and efficiently computerized. Think of database or model management.

Finally, we note that this position is controversial. For example, the case for use of nonstandard logics would seem to be even more transparent in the context of databases, yet in that literature the point is under contention. Even such authorities as C.J. Date oppose use of nonstandard logics in the context of databases [7]. We think he is wrong, but this issue has been joined elsewhere in the literature (especially in the database literature), and we choose to pass on discussion of it here.

**Digital Commerce as Formalized (Social) Action**

**Motivation: Computer-Mediated Action**

Our everyday world consists of a variety of physical entities such as houses, cars, people, and corresponding physical properties, such as color, size, and location. There are also a wide variety of nonphysical entities, properties,
and relationships. Examples include corporations, government agencies, departments in these organizations, one’s position of employment, ownership (of land, of objects), contracts, promises, rights, privileges, and so on. This is the social side of our world. It is putative—we believe in the existence of these things—yet, for the most part, not directly observable. Although we may recognize the buildings of a corporation, the legal entity itself is invisible. Likewise, we regularly acknowledge a wide variety of social properties and relationships—that Smith is a lawyer, that John and Alice are married, that Jones owns the house on the corner. Again, these are aspects that we do not directly observe: lawyerness, marriage, and ownership are not physical properties. What is the basis of our knowledge of this invisible world? It is not theoretical, in the way we know of atoms, electricity, and black holes. Rather, it is conventional. These conventions make our societies work. A promise to meet for lunch or a contract to build an airport are ways to achieve coordination of human behavior.

This leads us to consider the dynamics of the social world, how social entities, properties, and relationships are brought about, modified, and terminated. We refer to this as social action. Social actions are actions that change the social world. Although the action itself may be physical, such as the breaking of a bottle against a ship or raising one’s hand in an auction, they are most often linguistic actions, spoken or written pronouncements.

Initial theory for this was provided by the philosopher John Austin in How to Do Things with Words [2], where he introduced the notion of performative utterances. Unlike their informative counterparts, which merely describe the world (and are thus either true or false), performatives bring some change to it. A common example is a wedding ceremony, where an authorized individual, by saying “I now pronounce you husband and wife,” actually brings about the social relationship of marriage. This theory has subsequently been refined by Searle [47] as speech act theory and later given a more formal representation as illocutionary logic [48].

**Challenge: Illocutionary Primitives**

Messages for conducting business have to support assertions of fact, avowals of fact, and predictions, but also offers, acceptances, promises, and much else that is performative. These observations immediately suggest that speech act theory is fundamentally relevant to the design of communications systems for electronic commerce [22, 32, 42, 48]. Speech act theory views saying as a form of doing and has laid claim to providing a fundamental and universal framework for understanding linguistic communication. The philosopher John Searle is perhaps the leading exponent of the view that whatever can be said meaningfully can be expressed using the principles and categories of speech act theory. Although there is much attendant controversy, in the words of one commentator, “speech acts remain . . . one of the central phenomena that any general pragmatic theory must account for” [32]. Thus, empirical investigation is much needed. Examining the fit, or lack of fit, between speech act theory and the requirements of electronic commerce is an especially promising enterprise. If good fit is found, speech act theory is
confirmed and light is shed on how to formalize certain aspects of electronic commerce. If good fit is not found, speech act theory is seriously disconfirmed. In either event, the results are interesting.

Proponents of the illocutionary approach [6, 20, 25, 36, 37] have been convinced that speech act theory has much to recommend it as a logical basis for FLBC. If the strong claims for speech act theory of the sort made by Searle are even approximately correct, this could have profound and immediate consequences for the design of an FLBC. The reasoning for this may be put into an (enthymatic) argument:

1. Everything that can be said (a fortiori everything needed to be said in the conduct of business) is a speech act that falls into one of a small number of speech act categories (assertives, directives, commissives, etc.).

2. Effective and efficient interpretation of any message, whether by humans or by software systems, requires identification of the appropriate speech act category for the message. (In other words, speech act categories, such as the distinction between a request and an assertion, matter. Intelligent agents receiving a message will need to determine whether the message constitutes a request or is merely for information only.)

3. The speech act categories are significant from a practical point of view and support useful generalizations. (Here is a simple example: Commissives are a basic speech act category. We want to know everything we have committed to do; offers and acceptances are both ways of making a promise; making a promise is one way of acquiring a commitment to do something. Then to find everything one is committed to do, find everything that has been offered and every offer that has been accepted. Further, find everything entailed by doing what has been promised. Such important and rather simple inferences are not easily supported with present-day technology for electronic commerce.)

4. Therefore, speech act categories should be recognized as fundamental to the logic of any general FLBC.

Let us put the point another way: If, as maintained in a substantial independent body of literature, speech act theory is foundational for understanding linguistic communication, then all other relevant logical operators for an FLBC fall within the scope of the speech act operators. This is testable and, if true, would constitute a useful first step in designing a general-purpose, expressively powerful FLBC. Testing has begun. A recent analysis by Scott Moore [37] has demonstrated that speech act theory categories map well to the existing EDI message structure used by SWIFT. Further, Moore has also produced credible software prototypes that rely on a speech act theoretic FLBC and yield impressive functionality [25, 36]. In particular, he has developed three rather disparate prototypes (for office messaging, for simulating a simple
retail purchase, and for tracking and managing paperwork) that all use, and rely essentially on, a common FLBC (see [25] for further development of these points).

**Challenge: Deontic Reasoning**

Digital commerce encompasses communicating over networks, in the sense of exchanging information or data. More interestingly, it encompasses the actual *doing* of business over networks, that is, the formation and discharge of commitments. We want to be able to carry out formal, computational analysis of these commitment processes. As in other dynamic systems, commitment processes can be viewed as consisting of commitment states and commitment transitions.

One representational approach, just explained, focuses on the *transitions* of commitments, brought about as speech acts (illocutions). An alternative—perhaps dual—representational approach focuses on commitment *states*. The most relevant background theory for this is the area of so-called deontics, comprising formal theories of normative rules. This provides a set of foundational concepts for our analysis.

Efforts to formalize these concepts have developed under the heading of deontic logics (the name is derived from a Greek term meaning should or ought; see [14, 15]; for computational treatments, see [19, 51]). These are a variant of modal logic that contain operators applying potential behaviors or actions. The first axiomatization for deontic logic was proposed by von Wright [50]. As applied to electronic commerce, these deontic concepts provide a useful starting formalization of the notion of commitment (here taken to be contractual commitment).

An extension of the deontic notation that is especially relevant for digital commerce is the *agency* of deontic conditions (e.g., who is obligated; who is permitted), as well as the agency of deontic change (who imposes the obligation, who grants the permission). These agents are generally taken to be "legal persons," including people, companies, and government agencies. This might be denoted as \(x\Omega y\ F\), read as the obligation from \(x\) to \(y\) to see to it that \(F\). That is, \(x\) has the *commitment* to \(y\), to see to it that state \(F\) happens.

Several other aspects of deontics are relevant to electronic commerce. One of these is *sanctions*, that is, the negative consequences if a duty (obligation or prohibition) is violated. Such sanctions may be automatic—for example, the automatic charging of an overdraft fee by your bank—but often they are discretionary by the other party, as in a secured loan, whether or not to foreclose (for instance, some other remedy might be negotiated). Also, a judge’s decision on a suit is a sort of third-party discretion on sanctions. Another aspect is *dynamics*—that is, how deontic states change (see next section, on performatives). One final concept that is relevant, especially for security validation, is the notion of *defeasibility*, that is, that certain obligations, prohibitions, and the like may be overridden under special circumstances [44]. This is an essential characteristic for practical applications of deontic reasoning—that is, in the open world.

As indicated earlier, there is a kind of duality between the illocutionary
Figure 1. Changes in Deontic Status—Deontic Performatives

views and the deontic views (see [9]). Indeed, changes to deontic states may be brought about as kinds of illocutions. If we ignore the agency arguments introduced earlier, this might be characterized as the basic deontic (a) to oblige (someone to do something); (b) to forbid (someone from doing something); (c) to permit (someone to do something); (d) to waive (someone from having to do something). See figure 1 for a summary of these relationships.

Digital Commerce as Formal Conversation

Motivation: Open Electronic Commerce

Global information infrastructures are rapidly becoming a reality. Such worldwide networks help companies operate not only locally and regionally, but globally. For small and medium-size enterprises (SMEs) in particular, this offers tremendous opportunities to do global business electronically.5 Communication networks alone, however, are not sufficient to enable international electronic trade.

In the past it has been shown that the introduction of electronic data interchange (EDI) can have tremendous benefits for the efficiency of trading both between and within organizations (see, for instance, the proceedings of the annual EDI conference in Bled, Slovenia). On the other hand, it can also been shown that in many cases long and costly negotiations are necessary between the trading partners in order to establish the legal and contractual interpretation of the documents sent.6

The result is that most successful EDI implementations have been realized in what could be called “closed trading relationships,” in long-lasting trading relationships involving a large number of transactions between parties with a high level of trust and possibly a close coordination of the parties’ business processes (Table 1). In these kinds of relationships, which tend to ignore the legal and commercial uncertainties associated with new commercial relationships, parties can gain extra benefits by closely coordinating each other’s actions, thus compensating for the extra startup costs stemming from detailed trading partner negotiations. This might be cited as an example of business process redesign or reengineering. However, when the partnership
is established for a limited period, covering a few transactions only and on an “arm’s length” basis, EDI linkages are seldom observed, since the costs of the necessary negotiations cannot be recovered from the benefits. These shorter-term partnerships could be called “open trading relationships” (Table 1). The main aim of the EURIDIS research is to help lower the barriers for using EDI in these open trading relationships.

**Challenge: Electronic Trade Procedures**

A principal obstacle to the emergence of open electronic commerce is that parties have to know about each other’s “way of doing business” before they can start exchanging data electronically. Extra knowledge about the preferred way of doing business of one trading partner has to be conveyed to the other; in other words, the parties have to agree upon the trade scenario they are going to follow. A trade scenario is the mutually agreed upon set of rules governing the activities of each party involved in a kind of business transaction. Thus, a trade scenario controls all interactions between the roles involved. A trade scenario stipulates which actions should be undertaken by which parties, the order in which these actions should be performed, and possibly the timing constraints on the performance of these actions. Actions of parties include the sending and/or receiving of goods, documents, or funds.

The need and usefulness of trade scenarios are easy to demonstrate. Consider only a simple postpayment contract for goods. The buyer assumes that an invoice will be sent after delivery to trigger the payment obligation. The seller, on the other hand, abides by the practice that payment becomes due from the time of delivery and does not send an invoice. Thus, the goods arrive, and the buyer does not pay, waiting for an invoice. Meanwhile the seller becomes irked and initiates collection proceedings. This is an example of the so-called “battle of the forms.” Each party utilizes standardized documents such as a purchase order or delivery agreement, which contain (typically on the back side, in small print) the terms and conditions that are their style of doing business. Unfortunately, the small print is often ignored by the receiving party.

Furthermore, the same (electronic) document may have a fundamentally different legal or deontic meaning, depending on the context in which that document is sent [8]. For example, a purchase order sent as a response to a quotation is in most cases regarded as acceptance (thus establishing an obligation), whereas a purchase order sent without a previous offer will be considered an offer. For trade in a well-established industry area, standardized practice becomes generally accepted, and there usually is no problem.
ever, in more open trading situations that cross national, cultural, or sectoral boundaries, such conflicts are much more likely to arise.

This illustrates the need to define generic trade scenarios. Although the syntax and data-level semantics of EDI documents can be established by means of international standards such as UN/EDIFACT or ANSI X12, there are no standards yet for the business procedures that comprise the trade scenarios of a business transaction [52]. These trade scenarios might be stored in a publicly available repository, maintained by an international trade organization, or perhaps maintained by private organizations, for more specific uses.

In research at EURIDIS, Petri nets have been adopted to represent the temporal structure of trade scenarios, capturing both concurrency and choice in a unified way (see, e.g., [12, 41]). Petri nets have been well studied for their formal properties; various formal analysis techniques are available. Also, they provide a convenient graphical notation for modeling purposes. In addition, their broad popularity in other application domains (e.g., office processes) provides a useful basis of experience and modeler acceptance. Other representational requirements of electronic trade scenarios have led us to extend the basic Petri net representation in various ways. We call this extended form a documentary Petri net (DPN). These are explained in more detail in [4].

**Challenge: Audit Controls**

Of primary concern for open electronic commerce is whether the trade procedure invoked is actually secure from a legal and auditing standpoint. Unlike closed trading relationships, where such procedures may be carefully analyzed beforehand and debugged via continuing experience, open electronic commerce seems, by its nature, much more subject to loopholes and control weaknesses. Of particular concern is whether the trade procedure contains sufficient documentary evidence of each party’s actions, and that it have suitable controls for fraud and collusion. This points to the need for rapid, automated tools to audit trade procedures before they are employed in a particular situation.

An approach to developing this kind of auditing capability is based on a device we call an audit daemon. Audit daemons are drawn graphically using Petri net notation. They do not represent entire procedures, however, only localized segments or patterns in the procedure. Numerous audit daemons are applied to the object procedure, each looking for a possible weakness or fault. When an audit daemon matches the procedure, the user is given a diagnostic document. The auditing of procedures is thus somewhat similar to syntax checking in programming language compilers. However, the faults identified here are not simply syntactic, but focus on the semantic character of the procedure. Detailed discussion of these matters is available in [5].

**Challenge: Automated Trade Procedures**

To be effective, the trade procedures available for electronic commerce need to be flexible and adaptable. This means that they are not just fixed sequences
of documentary steps, but rather they may be tuned and adapted (within limits) to meet situation-specific requirements.

An approach is to have variations of a prototypical trade procedure generated "on-the-fly," based on specified situational objectives and constraints. To do this, we need to specify generic building blocks that can be flexibly combined to create a new procedure. The representation we have developed for these building blocks we call a procedure constraint grammar (PCG). As the name implies, the characteristics of each building block are conceptualized as constraints that the resulting procedure must satisfy. These are processed by a constraint resolution algorithm that identifies contentions and generates a procedure. The PCG representation has a certain resemblance to "definite clause grammars" (DCGs). However, rather than generating textual sentences, our use of the PCG is to generate documentary procedures. Additional details are presented in [28].

**Challenge: Agents to Negotiate Protocols**

There is an additional aspect of implementation of electronic trade procedures, namely, their negotiation among parties with different "ways of doing business." In the paper-based world, conflicts arise when the terms and conditions contained in the small print of standard business documents disagrees among the parties. (This is usually not detected until later, after a legal problem has arisen.) Insofar as electronic trade procedures are a computable version of this small print, conflicts can be detected early and resolved before transactions begin.

To help cope with such cases of conflicting trade procedure policies, we introduce an additional computational device that we call a messenger. A messenger is a kind of computational agent, specialized in navigating procedure libraries or regimes, and, where needed, negotiating procedural alternatives.

The notion of a messenger is based on the metaphor of physical messenger services (such as UPS or Federal Express). Such physical messengers are normally charged with delivering a message or parcel to some recipient. More important, they often make delivery of performative communications such as contractual offers (bids), legal summons, as well as payments. If obstacles arise (e.g., recipient is not home), the messenger has some limited discretion to resolve the problem (leave parcel at a neighbor's). If this is not possible, the messenger is to contact the client for further instructions. Our notion for electronic messengers goes beyond this physical metaphor to include not only the execution of certain contractual actions but also the navigation and (limited) negotiation of control procedures. Thus, messengers have four kinds of capabilities: (1) navigation of regimes (procedural requirements); (2) synthesis of procedures (from multiple regimes); (3) detection of procedural conflicts; and (4) suggestion of remedies for conflicts.

**Challenge: Agents to Negotiate Contracts**

Assuming that artificial agents can reliably and expressively send messages to one another, what must be done so that they may reliably and effectively
negotiate contract terms in complex environments? This question has been asked and attacked in the distributed AI literature, independently of considerations for electronic commerce. Considerable progress has been made in developing artificial agents that function in a cooperative environment. Most of this research has aimed at developing deterministic representations and negotiation models that are able to deal with a changeable environment that includes other, basically benign, agents (e.g., see [43, 45, 46]). Researchers working on this problem in business schools have tended to focus on the design of agents that (a) can learn and (b) can operate in environments in which it must be assumed that other agents are selfish and perhaps deceitful, rather than fundamentally benign. (Such environments are usually modeled with the apparatus of game theory.) Within this literature, two approaches are evident. First, researchers have engaged in mechanism design for agents in mixed-motive negotiation contexts, seeking thereby to determine the rules of the game so that agents may easily be instructed on how best to play. Usually, mechanism design aims also at producing games with socially favored properties (see [43, 45, 46]). Other researchers (see below on the works of Dworman, Kimbrough, Laing, and Oliver) have been impressed with the effective limitations of mechanism design and have aimed to explore how artificial agents perform under various machine learning regimes.

Initial results are available and quite promising for investigations on adaptive artificial agents in mixed-motive (game-theoretic) environments. Dworman, Kimbrough, and Laing [10] have demonstrated with genetic programming that artificial agents can coevolve and learn reasonably good bargaining strategies in three-agent coalitions games. Subsequently, they have compared the performance of the artificial agents with that of human subjects on equivalent games and found the artificial agents credible alternatives to humans [10, 11]. Oliver [39, 40] has investigated multidimensional negotiations by artificial agents, using genetic algorithms. Humans are known to perform poorly at such tasks, often “leaving money on the table” at the end of the negotiations. Oliver’s agents are often able, compared with humans in equivalent contexts, to extract more value from the negotiation. These initial results augur well for the day when artificial agents are able to learn effective negotiation strategies and to reliably conduct much commerce electronically.

**Design Support and User Interfaces**

**Management Aids for Network Enterprises**

**Research Question: How Can Management and Decision Functions Be Supported in Heterogeneous, Open-Ended, Multifirm Systems of Electronic Commerce?**

Electronic commerce adds value by providing new, more efficient, and more effective ways of performing business transactions. That in itself is ample
justification for the general excitement about electronic commerce. In addition, electronic commerce promises—and has to a degree delivered on this promise—to provide new, more efficient, and more effective means of managing the conduct of business transactions. It should be possible, for example, to develop general-purpose message-management systems that will automatically provide management information services for the business conducted via the messages they handle, as well as reduce the cost of implementing electronic commerce (see [23, 36, 38]).

**System Design Aids: INTERPROCS**

INTERPROCS is a graphical prototyping environment developed by Lee [28]. INTERPROCS offers a graphical user interface with which documentary Petri nets can be drawn. Further, since INTERPROCS is developed in Prolog, rule bases can be added to a documentary Petri net model, allowing various forms of automatic reasoning about modeled trade scenarios (discussed further below). Formal properties of trade scenarios, such as liveness and boundedness, can be analyzed using algorithms based on the formal properties of Petri nets.

INTERPROCS also provides the simulation of trade scenarios by animating the token flow of the Petri nets. In modeling with INTERPROCS, each role description is represented as a separate documentary Petri net using a separate window, possibly distributed across multiple machines. A view of the total trade scenario can be achieved by opening all windows containing the role descriptions. The communication between the roles is done by passing data between databases associated with each role. The exchange of goods is also represented as a data exchange among the roles.

The practical value of this prototyping environment is that it provides organizations with a method and a tool to define and test trade scenarios. Generic trade scenarios may be constructed either top–down or bottom–up. In the first case, an overall trade scenario will be distributed over the individual roles. In the second case, the individual role descriptions of the parties have to be combined. In either case, the role descriptions can be distributed over multiple machines, where documents may be exchanged over a local or wide area network using an EDI standard. This provides a realistic testing environment in which roles can be played and evaluated by different organizations.

Once tested and agreed upon, these scenarios might be stored in a public repository, governed by an international body. Since these scenarios are defined using a formal language such as the documentary Petri net formalism, it will be possible for organizations then to download and execute the scenarios. During this execution, the overall control of the trade scenario is distributed among the individual organizations.

**Interactivity and Customization**

One of the promises of electronic commerce is software-generated customization of sales and marketing interfaces. How, we ask, can electronic
shopping systems, tailored to particular users, be effectively and economically built and maintained? Research to date, which is only just beginning, has focused on two issues: (1) How should information be presented? and (2) How should information be structured internally?

The social benefits of an effective answer to the question of presentation are potentially enormous. Given the anticipated scale of consumer-based electronic shopping, even slight improvements in the speed and quality of the resulting decisions would yield enormous benefits. (The same point can be made about automated electronic commerce.) In the United States, a number of research projects are under way aimed at designing “electronic yellow pages” for effective display of information [33, 34]. Researchers interested in the second question, that dealing with internal structuring, have mainly been concerned to find representations that can reflect users’ preferences. Lee and Widmeyer [31] originally proposed a graph-based categorization scheme for electronic catalogs. An advantage of this scheme is that the representation can be treated as a measure of similarity for catalog items. Thus, guidance can be given automatically under either shortage (what the user wants is not available) or surplus (the user asks for an item in a given category and many alternatives are available). Isakowitz and Kimbrough [16] have generalized this representation to many dimensions and different degrees of similarity and have shown how the resulting representation may be used to encode a utility function. Whether this sort of approach will be practical is an intriguing, but at present quite open, question. On the larger issue of designing intelligent user interfaces for electronic shopping, we anticipate a theory-driven versus relevance-driven bifurcation of approaches. The theory-driven approach will investigate whether utility theory can effectively be brought into play to model users’ preferences, while the relevance-driven approaches will focus on creative uses of interactive multimedia (for example) and more qualitative representations of preference. The two approaches are complementary and, together, are very likely to yield significant advances.

**Multilingual Electronic Documents**

A key problem of international contracting is coping with differences in language. The obvious approach would be to apply natural-language translation techniques to this problem. While several machine translation (MT) systems have enjoyed some success, we believe that an alternative strategy is more appropriate and promising in the context of electronic commerce. This approach is essentially the reverse of natural-language recognition, focusing on text generation from structured input.

With respect to the data content of electronic documents, we utilize multilingual versions of electronic forms to structure the user’s input in his or her native language. In many cases, a similarly structured form can be used by the recipient, with data items and labels translated into his or her native language. Where necessary, text generation (using definite clause grammar rules) is used to produce the text of legal terms and conditions in the various languages (see, e.g., [30]).
A further challenge is to provide multilingual paraphrases of the electronic trade procedures. Insofar as these constitute a formal specification of the trading partner agreement, it will be necessary to deliver these to the judge and lawyers in cases of dispute. Given that legal training does not (yet) include background in formal representations, it will be necessary to provide a rigorously accurate reading of the trade procedure using appropriate legal language.

Closing Remarks

Let us recall our four basic questions and see how the foregoing, or at least the work referred to in the foregoing, has contributed to answering the questions.

1. The Possibilities Question

Everything depends upon effective communication, whether directly between buyers (customers) and sellers (producers) or indirectly via mediators. When this communication is formalized, so that it may be initiated and interpreted by automated processes (including artificial agents), a fascinating range of possibilities opens. Among the possibilities are these, mentioned above and independently demonstrated:

a. Automatic translation of (formalized) business documents into essentially any natural language;

b. Automated tailoring of user interfaces to reflect the preferences and experience of particular users;

c. Automated negotiation and learning of effective bargaining strategies in contexts that humans find challenging;

d. Automated generation and validation of business processes and procedures;

e. Automated handling of messages and responses to them;

f. Automated tracking and provision of management information for electronic transactions.

As rich and as substantial as this set is, other possibilities are manifold.11

2. The Requirements Question

In summary mode, we focus on three high-level requirements identified above:

a. Formal languages for business communications: Without these, intelligent agent communication for business applications will be limited and ad hoc. Such languages exist already, for example in the form of
EDI protocols, but are primitive and limited. These languages need to support temporal, deontic, and defeasible reasoning, as well as speech-act-theoretic categories. The logical challenges are formidable and much research will be required in order to realized the full potential of electronic commerce.

b. Formal models of business processes: Without these, reasoning by intelligent agents in electronic commerce will be severely constrained. Agents, or processes, must have knowledge of the context in which they work; automated agents must have this knowledge formally.

c. Sophisticated reasoning by intelligent agents: More than physical communication is needed for effective electronic commerce. If electronic commerce is to flourish and realize its potential, it must deliver substantial productivity improvements. This entails replacement of human labor with capital, here in the form of intelligent processes (software agents) that are able to replace such human activities as shopping, negotiation, and management of resources and commitments. If this is to happen, formal reasoning of some subtlety will have to occur in software.

3. The Technology Question

Throughout, we have assumed that the technology needed for effective and widespread electronic commerce is not a series of opportunistic, if clever, hacks, but principled and general representations, bolstered by deep understanding of business processes and requirements. This essentially entails the sort of formal and linguistic outlook permeating this paper. In the short run, particular solutions from particular vendors are likely to prevail in the marketplace. But in the long run, just as open systems in data processing have tended to replace proprietary systems (SNA, DECNet, etc.), so will it be in electronic commerce. Figuring out the formal and broadly logical details is, we believe, one of the supreme intellectual challenges of our time.

4. The Interpretation Question

What will all this mean? How will industries and individual lives be affected by powerful systems for electronic commerce? We do not know, and if we did we would not say so here. Instead, we offer a suggestion for how to find the answers to these questions. One approach, the easiest and most obvious, is to observe what is happening around us and try to discern meaning. While there is much value in doing this, the prospective confidence one can have in any particular predictions must be low. Can we recognize the Tocqueville of information technology except in retrospect?

More proactively, we can build, or use what others have built, and then evaluate experimentally. This opens a rich and exciting prospect for meaningful and relevant research contributions. Even if we focus only on formal
requirements, the requirements for electronic commerce listed here are very general and *prima facie* valid. The details matter. Exactly how will deontic reasoning by artificial agents prove useful, and why? Just how will artificial agents learn negotiation strategies well enough that we will turn over real authority to them? To date, the prospects and ideas have been enticing, but much hard work remains to translate them into effective and productive systems. Given the current rush of doubts about the productive value of information technology, as summarized for example by Landauer [27], what promises to be exciting research challenges for the IT research community will also be a practical necessity.

NOTES

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1. Apologies to Oscar Hammerstein and Jerome Kern (the authors of *Showboat*).
2. The term “commerce” should be taken in a broad sense to include business transactions generally, that is, to include activities of governmental and nonprofit organizations, as well as activities of private, profit-seeking corporations, and of individuals.
3. For instance, the ISO subcommittee for Open-edi, uses the lower-case acronym to refer to electronic data interchange in some (unspecified) generic sense, not limited to current EDI standards.
4. See also the distinction between brute and institutional facts discussed, e.g., by Searle [47].
5. For instance, the Preamble to the UNCTAD Symposium comments: “Trade efficiency measures would also result in reduction of trade transaction costs by a quarter or by up to 100 billion dollars annually by the year 2000” (1994, p. 3).
6. Baker gives an example of the size of such negotiations: “At one conference on EDI law, James Pitts, a purchasing manager at R.J. Reynolds, said he spent 18 months negotiating a single trading partner agreement. That left him with only 349 other trading partners to go.”
7. It should be noted, although we call these agreements “trade procedures,” the principle is applicable to societal areas other than trade. The main focus of this paper, however, is electronic commerce, which explains the term “trade” in the definition. Other terms used to describe this concept are “trade scenarios,” “business scenarios,” and “business protocols.”
8. In some cases, guidelines by international bodies such as the International Chamber of Commerce or the UNCID have been issued to diminish these ambiguities (an example is the Uniform Customs and Practices for Documentary Credits, issued by the ICC).
9. We use the term “procedure” to refer to the formalized, computable sequence of document exchanges and related deductions; the term “scenario” is used in a more informal and generic sense, referring not only to such procedures, but also to related informal explanations and contextualizations.
10. An ISO/IEC subcommittee, JTC1/SC30, is working on the definition of standard, EDI-based, trade scenarios. This initiative is called “Open-edi.” Open-edi is “EDI among autonomous, multiple participants using public standards and aiming towards inter-operability over time, business sectors, information technology systems and data types, capable of multiple, simultaneous transactions, to accomplish a explicit shared business goal” [18]. The main goal of Open-edi is to lower the barriers for the establishment of EDI links between business partners by
minimizing the need for multiple, bilateral Interchange Agreements. This will be
done by providing industry-wide and/or cross-sectoral Open-edi standards, which
will be available to all parties involved in a business transaction.

11. DecisionNet, the brainchild of Hemant Bhargava and Ramayya Krishnan, is
a fascinating prototype example of how mediators may be largely automated, thus
providing potentially enormous efficiencies in electronic markets. See [3].

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For the authors' biographical sketches, see the Guest Editors' Introduction.