

# What is Commitment?

## Physical, Organizational, and Social

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**Abstract.** This paper uses Participatory Semantics to explicate commitments.

*Information* expresses the fact that a system is in a certain configuration that is correlated to the configuration of another system. Any physical system may contain information about another physical system

For the purposes of this paper, *physical commitment* is defined to be *information* about *physical systems* (situated at a particular place and time). This use of the term *physical commitment* is currently nonstandard

Note that commitment is defined for *whole physical system*; not just a participant or process. *Fidelity* of commitment is defined to be the *strength* of the relationship between information and physical system.

Organizational and social commitments can be analyzed in terms of physical commitments. For example systems that behave as scientific communities can have commitments for *monotonicity*, *concurrency*, *commutativity*, *pluralism*, *skepticism*, and *provenance*.

Actors rise to the level of “*Agenthood*” when they *competently* use *expressions* of commitments expressing intention, dedication, judgment, decision, proposal, plan, contract, purpose, belief, policy, method, procedure, practice, backing, questioning, *etc.*

Speech Act Theory has attempted to formalize the semantics of some kinds of expressions for commitments. Participatory Semantics for commitment can overcome some of the lack of expressiveness and generality in Speech Act Theory.

## 1 Introduction

This paper uses Participatory Semantics [Hewitt and Manning 1996] as formalism within which to explicate commitment. Participatory Semantics makes use of participations that are 4-dimensional regions of space-time. Participations include both happenings (regions in which things happen, e.g., purchasing, communicating, etc.) and participants (regions for things that participate, e.g., people, XML expressions, etc.). Participatory Semantics derives from concepts in physics (e.g. quantum, relativistic).

## 2 Information

Information expresses the fact that a system is in a certain configuration that is correlated to the configuration of another system. Any physical system may contain information about another physical system.

### 2.1 Information is necessarily incomplete

Although Einstein was one of the first to formulate the necessary incompleteness of quantum physics, he never fully accepted it.

Chris Fuchs [2002] summed up the reality of the necessary incompleteness of information in quantum physics as follows:

“Incompleteness, it seems, is here to stay: The theory prescribes that no matter how much we know about a quantum system—even when we have maximal information about it—there will always be a statistical residue. There will always be questions that we can ask of a system for which we cannot predict the outcomes. In quantum theory, maximal information is simply not complete information Caves and Fuchs [1996]. But neither can it be completed.”

The kind of information about the physical world that is available to us according to Fuchs [2002] is “the potential consequences of our experimental interventions into nature” which is the subject matter of quantum physics.

### 2.2 Information is relational

According to Relational Quantum Physics [Laudisa and Rovelli 2005], the way distinct physical systems *affect each other* when they interact (and not of the way physical systems “are”) exhausts all that can be said about the physical world. The physical world is thus seen as a net of interacting components, where there is no meaning to the state of an isolated system. A physical system (or, more precisely, its contingent state) is reduced to the net of relations it entertains with the surrounding systems, and the physical structure of the world is identified as this net of relationships. In other words, “*Quantum physics is the theoretical formalization of the experimental discovery that the descriptions that different observers give of the same events are not universal.*”

The concept that quantum mechanics forces us to give up the concept of a description of a system independent from the observer providing such a description; that is the concept of *the absolute state of a system*. I.e., there is no observer independent data at all. According to Zurek [1982], “*Properties of quantum systems have no absolute meaning. Rather they must be always characterized with respect to other physical systems.*”

Does this mean that there is no relation whatsoever between views of different observers? Certainly not. According to Rovelli [1996] “*It is possible to compare different views, but the process of comparison is always a physical interaction (and all physical interactions are quantum mechanical in nature).*”

## 3 Actors and Events

Actors are the universal primitives of concurrent digital computation. In response to a message that it receives, an Actor can make local decisions, create more Actors,

send more messages, and designate how to respond to the next message received. A Serializer is an Actor that is continually open to the arrival of messages. Messages sent to a Serializer always arrive although delivery can take an unbounded amount of time. (The Actor model can be augmented with metrics.)

*Unbounded nondeterminism* is the property that the amount of delay in servicing a request can become unbounded as a result of arbitration of contention for shared resources *while still guaranteeing that the request will eventually be serviced*.

Arguments for unbounded nondeterminism include the following:

- There is no bound that can be placed on how long it takes a computational circuit called an *Arbiter* to settle.
  - Arbiters are used in computers to deal with the circumstance that computer clocks operate asynchronously with input from outside, "e.g.", keyboard input, disk access, network input, "etc."
  - So it could take an unbounded time for a message sent to a computer to be received and in the meantime the computer could traverse an unbounded number of states.
- Electronic mail enables unbounded nondeterminism since mail can be stored on servers indefinitely before being delivered.
  - Communication links to servers on the Internet can be out of service indefinitely.

This section focuses on just those events that are the arrival of a message sent to an Actor.

### 3.1 Activation ordering

The activation ordering ( $\rightarrow$ ) is a fundamental transitive ordering that models one event activating another (there must be energy flow from an event to an event which it activates).

### 3.2 Arrival orderings

The arrival transitive ordering of an Actor  $x$  ( $\rightarrow_x$ ) models the (total) ordering of events in which a message arrives at  $x$ . Arrival ordering is determined by arbitration in processing messages (often making use of arbiters).

Hewitt [1985], Hewitt and Agha [1991], and other published work argued that mathematical models of concurrency did not determine particular concurrent computations as follows: The Actor model makes use of arbitration for determining which message is next in the arrival ordering]of an Actor that is sent multiple messages concurrently. For example *Arbiters* can be used in the implementation of the arrival ordering of an Actor which is subject to physical indeterminacy in the arrival order.

In concrete terms for Actor systems, typically we cannot observe the details by which the arrival order of messages for an Actor is determined. Attempting to do so affects the results and can even push the indeterminacy elsewhere. Instead of observing the internals of arbitration processes of Actor computations, we await outcomes. Physical indeterminacy in arbiters produces indeterminacy in Actors. The reason that we await outcomes is that we have no alternative because of indeterminacy.

According to Chris Fuchs [2004], quantum physics is a theory whose terms refer predominately to our interface with the world. It is a theory not about observables, not about *beables*, but about ‘*dingables*.’ We tap a bell with our gentle touch and listen for its beautiful ring.

The semantics of indeterminacy raises important issues for autonomy and interdependence in information systems. In particular it is important to distinguish between *indeterminacy* in which factors outside the control of an information system are making decisions and *choice* in which the information system has some control.

It is not sufficient to say that indeterminacy in Actor systems is due to unknown/unmodeled properties of the network infrastructure. The whole point of the appeal to indeterminacy is that aspects of Actor systems can be *unknowable*.

### 3.3 Combined ordering

The combined ordering (denoted by  $\rightarrow$ ) is defined to be the transitive closure of the activation ordering and the arrival orderings of all Actors.

The combined ordering is obviously transitive by definition.

For all events  $e_1, e_2$  if  $e_1 \rightarrow e_2$ , then the time of  $e_1$  precedes the time of  $e_2$  in the frame of reference of every relativistic observer.

*Law of Strict Causality for the Combined Ordering:* For no event  $e$  does  $e \rightarrow e$ .

### 3.4 Discreteness

Discreteness captures an important intuition about computation: it rules out counterintuitive computations in which an infinite number of computational events occur between two events (à la Zeno).

*Finite Chains Between Events in the Combined Ordering:* There are no infinite chains (*i.e.*, linearly ordered sets) of events between two events in the combined ordering  $\rightarrow$ .

The property of Finite Chains Between Events in the Combined Ordering is closely related to the following property:

*Discreteness:* For all events  $e_1$  and  $e_2$ , the set  $\{e \mid e_1 \rightarrow e \rightarrow e_2\}$  is finite.

Theorem [Clinger 1981]: *Discreteness of the combined ordering is equivalent to the property of Finite Chains Between Events in the Combined Ordering* (without using the axiom of choice.)

### 3.5 Law of Discreteness of Combined Ordering in the Actor Model

However, we know from physics that infinite energy cannot be expended along a finite trajectory. Therefore, since the Actor model is based on physics, the Discreteness of the Combined Ordering was taken as an axiom of the Actor model.

The above described Actor event structures can be used as the basis to construct a denotational model of Actor systems as described in the next section.

## 4 Denotational Semantics

The task of denotational semantics is to construct *denotations* for concurrent systems that are all the possible behaviors that can be exhibited by the system.

We can use Actor event diagrams to help construct denotations where an Actor event *diagram* is just an initial history of the evolution of a concurrent system making use of the combined ordering.

#### 4.1 Domain of Timed Actor Computations

Related to the work of Clinger [1981], we will construct an  $\omega$ -complete computational domain for Actor computations.<sup>1</sup> In the domain constructed here, for each event in an Actor computation, there is a delivery time which represents the time at which the message is delivered such that each delivery time satisfies the following conditions:

1. The delivery time is a positive rational number that is not the same as the delivery time of any other message.
2. The delivery time is more than a fixed  $\delta$  greater than the time of its activating event. It will later turn out that the value  $\delta$  of doesn't matter. In fact the value of  $\delta$  can even be allowed to decrease linearly with time to accommodate Moore's Law.

The Actor event timed diagrams form a partially ordered set  $\langle \mathbf{TimedDiagrams}, \leq \rangle$ . The diagrams are partial computation histories representing "*snapshots*" (relative to some frame of reference) of a computation on its way to being completed. For  $d1, d2 \in \mathbf{TimedDiagrams}$ ,  $d1 \leq d2$  means  $d1$  is a stage the computation could go through on its way to  $d2$

The completed elements of  $\mathbf{TimedDiagrams}$  represent computations that have terminated and nonterminating computations that have become infinite. The completed elements may be characterized abstractly as the maximal elements of  $\mathbf{TimedDiagrams}$ . Concretely, the completed elements are those having no pending events.

Theorem:  $\mathbf{TimedDiagrams}$  is an  $\omega$ -complete domain of Actor computations *i.e.*,

1. If  $D \subseteq \mathbf{TimedDiagrams}$  is directed<sup>2</sup>, the least upper bound  $\mathbf{VD}$  exists; furthermore  $\mathbf{VD}$  obeys all the Actor laws.
2. The finite elements of  $\mathbf{TimedDiagrams}$  are countable where an element  $x \in \mathbf{TimedDiagrams}$  is *finite* (isolated) if and only if  $D \subseteq \mathbf{TimedDiagrams}$

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<sup>1</sup>  $\omega$ -complete means that limits exist. The work here stands in contrast to Clinger [1981] which constructed an  $\omega$ -complete power domain from an underlying incomplete diagrammatic domain, which did not include time. The advantage of the domain  $\mathbf{TimedDiagrams}$  constructed here is that it is physically motivated and the resulting computations have the desired property of  $\omega$ -completeness (therefore unbounded nondeterminism) which provides guarantee of service.

<sup>2</sup> A subset  $A$  of a partially ordered set  $\langle P, \leq \rangle$  is called a *directed* subset if and only if  $A$  is not the empty set and if  $a, b \in A$ , there exists a  $c \in A$  with  $a \leq c$  and  $b \leq c$  (*directedness*).

is directed and  $x \leq \vee D$ , there exists  $d \in D$  with  $x \leq d$ . In other words,  $x$  is finite if one must go through  $x$  in order to get up to or above  $x$  via the limit process.

3. Every element of **TimedDiagrams** is the least upper bound of a countable increasing sequence of *finite* elements.

## 4.2 Power domains

Definition: The domain  $\langle \text{Power}[\text{TimedDiagrams}], \subseteq \rangle$  (after Clinger [1981] with the *crucial difference* that in this work the domain **TimedDiagrams** is  $\omega$ -complete) is the *set* of possible initial histories  $M$  of a computation such that

1.  $M$  is downward-closed, *i.e.*,

$$\text{if } d \in M, \text{ then } \forall d' \in \text{TimedDiagrams } d' \leq d \Rightarrow d' \in M$$

2.  $M$  is closed under least upper bounds of directed sets, *i.e.* if  $D \subseteq M$  is directed, then  $\vee D \in M$

Note: Although  $\text{Power}[\text{TimedDiagrams}]$  is ordered by  $\subseteq$ , limits are not given by  $\cup$ . *I.e.*,

$$\forall i \ M_i \subseteq M_{i+1} \Rightarrow \bigcup_{i \in \omega} M_i \subseteq \bigvee_{i \in \omega} M_i$$

*E.g.*, If  $\forall i \ d_i \in \text{TimedDiagrams}$  and  $d_i \leq d_{i+1}$  and  $M_i = \{d_k \mid k \leq i\}$  then

$$\bigvee_{i \in \omega} M_i = \bigcup_{i \in \omega} M_i \cup \{\bigvee_{i \in \omega} d_i\}$$

Theorem:  $\text{Power}[\text{TimedDiagrams}]$  is an  $\omega$ -complete domain.

## 4.3 Denotations

An Actor computation can progress in many ways.

Let  $d$  be a diagram with next scheduled event  $e$  and  $X \equiv \{e' \mid e \xrightarrow{\text{1-message}} e'\}$ ,

$\text{Flow}(d)$  is defined to be the set of all diagrams with  $d$  and extensions of  $d$  by  $X$  such that

1. the arrival all of the events of  $X$  has been scheduled where
2. the events of  $X$  are scheduled in all possible orderings among the scheduled future events of  $d$
3. subject to the constraint that each event in  $X$  is scheduled at least  $\delta$  after  $e$  and every event in  $X$  is scheduled at least once in every  $\delta$  interval after that. (Please recall that  $\delta$  is the minimum amount of time to deliver a message.)

$$\text{Flow}(d) \equiv \{d\} \text{ if } d \text{ is complete.}$$

Let  $S$  be an Actor system,  $\text{Progressions}_S$  is a mapping

$$\text{Power}[\text{TimedDiagrams}] \rightarrow \text{Power}[\text{TimedDiagrams}]$$

$$\text{Progression}_S(M) \equiv \bigcup_{d \in M} \text{Flow}(d)$$

Theorem:  $\text{Progression}_S$  is  $\omega$ -continuous.

I.e., if  $\forall i M_i \subseteq M_{i+1}$  then

$$\text{Progression}_S(\bigvee_{i \in \omega} M_i) = \bigvee_{i \in \omega} \text{Progression}_S(M_i)$$

Furthermore the least fixed point of  $\text{Progression}_S$  is

$$\bigvee_{i \in \omega} \text{Progression}_S^i(\perp_S)$$

where  $\perp_S$  is the initial configuration of  $S$ .

The denotation  $\text{Denote}_S$  of an Actor system  $S$  is the set of all computations of  $S$ .

Define the *time abstraction* of a diagram to be the diagram with the time annotations removed.

Representation Theorem: The denotation  $\text{Denote}_S$  of an Actor system  $S$  is the *time abstraction* of

$$\bigvee_{i \in \omega} \text{Progression}_S^i(\perp_S)$$

where the time abstraction of a diagram is obtained by simply omitting the timing information.

Using the domain **TimedDiagrams**, which is  $\omega$ -complete, is important because it provides for the direct expression of the above representation theorem for the denotations of Actor systems by directly constructing a minimal fixed point.

In future work it will be shown how the representation theorem can be used as the basis for model checking to verify properties of Actor systems.

The previous sections on the Actor model provide a basis for grounding concurrent computation in space-time. This grounding provides part of the foundation for the next sections on commitment.

## 5 Commitment

Various notions of commitment have been proposed around the notion of *something pledged*.

### 5.1 What is physical commitment?

For the purposes of this paper, *physical commitment* is defined to be *information* about *physical systems* (that are situated at a particular place and time). Note that physical commitment is defined for *whole physical systems*; not just a participant or process. Participants and/or processes might be entangled!

*Fidelity* of physical commitment is defined to be the *strength* of the relationship between information and physical system. Fidelity is *another* physical commitment that is the relationship between information backing the strength of commitment and the physical situation.

Let  $K$  be the expressed knowledge of physical commitment for how a large number of people interact with their information systems. I claim that  $K$  is inconsistent. Such inconsistencies can be addressed in Direct Logic [Hewitt 2006].

The use of physical commitment here differs from the previous work of Bratman, Cohen, Durfee, Georgeff, Grosz, Huber, Hunsberger, Jennings, Kraus, Levesque,

Nunes, Pollack *etc.* in that it is not founded on the notion of psychological beliefs, desires, intentions, and goals.

## 5.2 Physical commitment and contracts

A contract *C* is a signed (XML) expression for a physical commitment that states how certain parties *P* are to behave. In the course of time the parties *P* can fall into and out of compliance with the contract *C*.

Since *C* is a finite and of limited expressiveness there is a great deal of behavior by *P* that is left unspecified or ambiguous by *C*. Given these limitations, it might be that *C* is clarified, amended, or even completely revised in the course of time.

Furthermore various participants might actually see things differently as to whether the parties *P* are complying with *C*. For example violations might not be detected for some time or might not ever be detected. Participants who detect violations may or may not be members of *P*.

Also *C* might contain escape clauses such that the commitment might become trivialized. For example *C* might contain a time limit such that it is no longer in force after a certain time.

Sometimes some of the parties *P* do not fulfill *C* or desire to deviate from *C*. In some cases violations are innocent, unintentional, or cannot reasonably be avoided. In other cases some members of *P* may deliberately violate *C* perhaps even concealing what they are doing.

## 5.3 Organizational commitments

Organizational commitments are physical commitments that are undertaken by organizations.

Organizational commitments can be represented in contracts by having an organization sign a contract as opposed to an individual. For example, it is common for organizations to sign executable code for computers which commits that the organization is the originator of the code.

Often an organization will not entrust its entire authority to just one signature. So a system of delegation is established in which another signature might be granted a limited amount of organizational authority. This can be accomplished by a contract signed by a higher authority delegating certain specified abilities to another signature. In many cases, this delegation can be revoked at a later time.

## 5.4 Social commitments

Social commitments involving permissions and obligations have been the subject of previous research by [Bergeron and Chaib-draa 2005], [Castelfranchi 1997], [Flores, Pasquier and Chaib-draa 2004], [Fornara, Vigano and Colombetti 2004], [Jennings 1993], [Louis and Martine 2005] and [Mallya and Singh 2004], *etc.*

[Fornara, Vigano and Colombetti 2004] proposed that a social commitment can be characterized by the following attributes:

- *debtor*: owes the *content* to the *creditor*
- *creditor*: is owed the *content* by the *debtor*
- *content*: a temporal proposition that at every time instant has a truth value that can be one of the following: *undefined*, *true*, or *false*.



- *state*: which is obtained by the actions `makeCommitment`, `setCancel`, `setPending` and must be one of the following: *unset*, *pending*, *cancelled*, *fulfilled*, or *violated*.

Similarly in [Singh and Huhns 2005], a social commitment has attributes of *debtor*, *creditor*, *condition* the debtor is to bring about, and *organizational context*.

A social commitment as characterized in the above work can be considered a special case of physical commitment (as defined in this paper) between information with the required attributes and the physical system of the *debtor* and *creditor* during the time periods in question.

### 5.6 Inconsistent Social Commitments

Social commitments are analyzed in terms of permissions, obligations, prohibitions, dispensations, and delegations in [Kagal and Finin 2004] where meta-policies are used to attempt to remove some inconsistencies. As an example, they describe the recent issue with the passage of the Medicare prescription drug bill in the United States:

**USGovStaff(p)  $\Rightarrow$  obligated(p, answerCongressionalQuery(p))**  
**USGovStaff(Foster)**  
**boss(p1, p2)  $\wedge$  order(p1, p2, s)  $\Rightarrow$  obligated(p, s)**  
**boss(Scully, Foster)**  
**order(Scully, Foster,  $\neg$ answerCongressionalQuery(Foster))**

The above example has Foster faced with inconsistent social commitments when he received a query from the congressional Democrats on the estimated cost of the Medicare prescription drug bill since the derivation of

**obligated(Foster, answerCongressionalQuery(Foster))**

is contradicted by the derivation of

**obligated(Foster,  $\neg$ answerCongressionalQuery(Foster))**

The study of the inconsistent physical commitment can be addressed in Direct Logic which has been developed to deal with this kind of inconsistent information (for a preliminary version of Direct Logic see Hewitt [2006]).

### 5.7 Psychological Commitments

Psychological commitments have been studied in Artificial Intelligence by Bratman, Cohen, Georgeff, Grosz, Harman, Huber, Hunsberger, Jennings, Kraus, Levesque, Nunes, Pollack, Sidner, Singh, *etc.*

Psychological commitments are subject to certain pitfalls including the following:

- *omniscience of deductive consequence*: Typically psychological commitments have been based on psychological beliefs. However, an Agent cannot be expected to be psychologically committed to *all* the deductive consequences of their beliefs because of combinatorial intractability.
- *mentalism*: Psychological commitments have been widely criticized as being based on mentalism which makes them subject to great uncertainty because the current state of development in Artificial Intelligence. Such mentalism was the subject of great controversy in the 1991 AAAI Fall Symposium on Knowledge and Action at Social and Organizational Levels.

Consider for example the following conundrum from [Flores and Pasquier 2005]:

“When agents commit to something, they commit to satisfying a condition, which is usually represented as a proposition. Committing to a proposition means that the

debtor is responsible either for making it true, or for believing that it is true. This ambiguity is apparent in commitments about the past or the future. If proposition  $a$  was "It rained yesterday", and agent  $y$  was committed to  $a$ , then  $y$  is responsible for satisfying  $a$ . Given the limitations of earthly things, it is safe to assume that this commitment implies that  $y$  comes to *believe* the truthfulness of  $a$ , not that she will *make an effort* to make it happen. Of course, if  $y$  could induce rain and travel through time, then  $a$  could entail that  $y$  is committed to making this happen. However, since time travel is not a reasonable ability, it can be assumed that  $a$  appeals solely to her state of mind, i.e., that she believes that  $a$  is true."

For the purposes of this paper, we can suppose that on July 5, 2005 agent  $y$  signed a contract  $a$  to the effect that "It rained in Boston on July 4, 2005." A relevant physical commitment is the relationship between the physical situation of  $y$  on July 5, 2005 and the information that  $y$  signed the contract  $a$  on July 5, 2005. As defined in this paper, the physical commitment *doesn't say anything at all about the state of mind of  $y$  when  $y$  signed  $a$* . However, there may be another *different* legal commitment to which  $y$  is subject as a result of signing  $a$ .

The above example shows how the notion of physical commitment as defined in this paper is not making the kind of psychological assumptions that are involved in [Flores and Pasquier 2005], *etc.*

### 5.7 Electronic Institutions

[García-Camino, Noriega, and Rodríguez-Aguilar 2005] presented an analysis in terms of a normative framework of obligations, permissions, prohibitions, violations, and sanctions, which can be formalized in terms of physical commitment.

For example consider the commitment to be a *Fishmarket* in which buyers submit bids to an auctioneer in a Dutch auction to purchase round lots of fish. A proper *Fishmarket* provides that

- its participants have particular obligations, permissions, and prohibitions
- that certain violations may occur
- if violations occur, what sanctions are imposed

It is possible to implement an actual fish market in the form of an electronic institution (*e.g.* as described in [Noriega 1997]) in which information technology plays an important role in the operations of obligations, permission, prohibitions, and sanctions. Once this has been done (*e.g.* in Blanes) we can look at the physical commitment that the fish market in Blanes operates as a proper *Fishmarket* at some particular time (*e.g.* 12 December 1997). In this regard, it would be possible to have every participant take part in a full audit on 13 December 1997 of what happened the previous day and then sign a contract that to the best of their knowledge all of the *Fishmarket* obligations, permissions, prohibitions, and violations had been obeyed on the previous day. However, although they are evidence, just by themselves, these contracts may not definitely settle the question as to whether a proper *Fishmarket* operated in Blanes on 12 December 1997. *E.g.*, error or fraud (large or small) may still be a possibility.

## 6 Agenthood

Actors rise to the level of “*Agenthood*” when they *competently* process expressions for commitments including the following:

Contracts	Announcements
Beliefs	Goals
Intentions	Plans
Policies	Procedures
Requests	Queries

There are various characterizations of *Agent* in the literature (*e.g.* Brustoloni, Coen, Ferber, Foner, Franklin, Graesser, Hayes-Roth, Huhns, Jennings, Maes, Norvig, Russell, Singh, Spohrer, Virdhagriswaran, Wooldridge, *etc.*). Also see Castelfranchi [1999] on agenthood. However these are unsatisfactory in their informality. Nick Jennings once quoted the author of this paper to the effect that the question “What is an Agent?” is as embarrassing in AAMAS as the question “What is intelligence?” is in AI. This is echoed in the overview of software agents by Nwana [1996] which states “We have as much chance of agreeing on a consensus definition for the word *agent* as AI researchers have of arriving at one for *Artificial Intelligence* itself - nil!”

## 7 Speech Act Semantics

Speech Act Theory has been developed by philosophers and linguists to account for the use of language beyond simply stating propositions as in mathematical logic. Speech Act Theory encompasses *perlocutionary* and *illocutionary* semantics.

### 7.1 Limitations of Perlocutionary Semantics

The perlocutionary semantics of a speech act the effect, intended or not, achieved in an addressee by a speaker’s utterance, *e.g.*, persuading, convincing, scaring, insulting, getting the addressee to do something. However, perlocutionary semantics is limited in scope to physical state of addressee. In terms of physics, the addressee is a dingable! In fact the speaker and addressee may be entangled and even privately interacting unbeknownst to an observer.

### 7.2 Limitations of Illocutionary Semantics

The illocutionary semantics of a speech act is the basic purpose of a speaker in making an utterance, *e.g.*, *Assertive*, *Commissive*, *Declarative*, or *Expressive* as follows:

- *Assertive*: The speaker expresses that the state of affairs described by the propositional content of the utterance is actual.
- *Commissive*: The speaker expresses that they are committed to bring about the state of affairs described in the propositional content of the utterance.
- *Declarative*: The speaker expresses that they are bringing into existence the state of affairs described in the propositional content of the utterance.
- *Directive*: The speaker expresses that they are attempting to get someone to bring about the state of affairs described by the propositional content of the utterance.

- *Expressive*: The speaker expresses that they are communicating an attitude or emotion about the state of affairs described in the propositional content of the utterance.

Illocutionary semantics is limited in scope to the psychological state of a speaker. However, it is unclear how to determine psychological state! Also commitments don't fall neatly into the pigeonholes specified by speech act theorists. Furthermore the speaker and addressee may be entangled.

### 7.3 Web Services

FIPA attempted to promote Agent Communication Languages based on Speech Act Theory. This pioneering effort ran into many difficulties including the problem of trying to pigeonhole communications into the FIPA prescribed illocutionary performative communicative acts whose semantics are expressed terms of psychological beliefs [FIPA 2000].

Subsequently attention has turned to Web Service standardization. However the current Web Services standards lack formal semantics.

## 8 Prospects and Future Work

On the 40th anniversary of the publication of Moore's Law, hardware development is furthering both local and nonlocal massive concurrency. Local concurrency is being enabled by new hardware for 64-bit many-core microprocessors, multi-chip modules, and high performance interconnect. Nonlocal concurrency is being enabled by new hardware for wired and wireless broadband packet switched communications. Both local and nonlocal storage capacities are growing exponentially. All of the above developments favor the Actor model.

Prospects for Agents are more difficult to estimate. Currently Web Services do not assign any large role to Agents. On the other hand the semantics of *commitment* and *Agenthood* whose development is furthered in this paper are crucial to the future development of Web Services. So one issue before us is what science, technology and terminology will Web Services use for these concepts going forward.

For our future Agent systems research, we will need to take the following measures: Make extensive use of monotonicity, commutativity, pluralism, skepticism, and provenance. Use (binary) XML to express commitments organizing them in viewpoints (theories, contexts) making use of inheritance and translation. Develop semantics for processing expressions for commitments. Develop formal semantics for Web Services. Study how human individuals, organizations, and communities process expressions for commitments using psychology, sociology, and philosophy of science. Prepare for the semantic consequences of massive concurrency both local (many-cores) and nonlocal (Web Services).

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