Understanding Human Communication Acknowledgement Protocols By Studying Artificial Communication Protocols

Stefan Brandle
Department of Computer Science and Applied Mathematics
Illinois Institute of Technology
Chicago, IL 60616 -- brandle@charlie.acc.iit.edu

Abstract: Human communication is powerful and overall successful, not entirely because of the immediate accuracy in understanding utterances, but in part due to the communicating parties ability to dynamically detect and correct problems as they arise. Acknowledgements are key to this process of monitoring communication to determine whether the quality of the communication is a acceptably high. In studying natural language and human communications protocols, a problem we face is that by the time we are old enough to become interested in the underlying mechanisms, those mechanisms have become so automatic that we have difficulty observing them. As I study natural language, I supplement the direct study of acknowledgements in our corpus of human communication transcripts, by studying artificial communication protocols, and then apply that knowledge back to the study of human protocols.

1. Introduction And Background

My natural language research group studies linguistic phenomena in the context of the continuing development of an intelligent tutoring system, CIRCSIM-Tutor. This intelligent tutoring system (ITS) uses natural language to tutor medical students in understanding the cardiovascular circulatory system. One of the problems facing ITSs such as ours is the loss of much of the subtle human communication acknowledgement information such as facial expressions, gestures, speech volume, timing and intonation that are normally available. That is, these systems must deal with communication signal information loss. ITSs also face problems at higher acknowledgment levels in dealing with issues such as determining what to expect in an utterance, recognizing whether an utterance matches what would normally be expected in the context, and determining the implications of what is actually said and what is not said. Accessing much of this information is beyond the current state of the art, but it is my belief that we can do much more with the information available to us, namely the text typed in at the keyboard, some coarse timing information, and simple matching of inter-turn utterance expectations with what is actually typed by the student.

This work was supported by the Cognitive Science Program, Office of Naval Research under Grant No. N00014-94-1-0338, to Illinois Institute of Technology. The content does not reflect the position or policy of the government and no official endorsement should be inferred.

A good starting point for dealing with acknowledgements in natural language is to study acknowledgements and develop a theory--and taxonomy--of acknowledgement protocols. My study includes analyzing transcripts, but one of the problems with doing that lies in the transparency of these linguistic mechanisms to people who have been using them their whole lives. This paper details an attempt to supplement the study of our transcript data corpus by stepping outside the normal frame of our communication mechanisms to study an artificial communications system--computer communications--and its associated acknowledgement protocols, and then to apply the results to the study of human communication with the hope of obtaining greater insight into human communications protocols.

2. A Taxonomy Of Acknowledgements In Computer Communications

A major advantage of studying computer communications in order to gain insight into acknowledgement protocols is that it is a field which is so young that we are still learning the requirements for successful and efficient communication, and consequently are very much aware of the necessary mechanisms. Another advantage is that we have had to explicitly develop the acknowledgement protocols as we develop hardware and software, and thus we tend to be much more aware of the mechanisms.

Based on my experience with the management, programming, and formal study of computer communications, I have developed a list of kinds of acknowledgements which is formed into a taxonomy of acknowledgements in communications. A detailed treatment of computer communications is beyond the scope of this paper, but here is a summary of the ideas.

Dealing with computers is notoriously prone to error and failure. This is especially true of computer communications where there are problems with data being damaged, data getting completely lost, computers dropping connections, etc. To guarantee reliable communication, the developers of communications systems must verify all communication and do so rigorously. So when data is sent from one computer to another, unless a clear positive acknowledgement is received at some point, the worst is believed and the data must be retransmitted. There are ways to cut down on the overhead of constantly verifying the safe communication of information, but the bottom line is that ultimately all communication not unequivocally verified must be considered failed. This leads to painstaking development of communications protocols and makes the study of computer communications very rewarding as a technique of studying communication in general.

I have found the following acknowledgement categories in computer communications: 1) positive acknowledgement, 2) negative acknowledgement, 3) delayed acknowledgement, 4) lost acknowledgement, 5) subsumed acknowledgement, 6) link keep-alive signal, 7) request for acknowledgement (polling), 8) flow control, 9) protocol negotiation, 10) dynamic link quality adjustment, and 11) error correction. This list is not expected to be exhaustive, but it is sufficient to test the viability of studying artificial communications in order to supplement the study of natural language. (Tanenbaum, 1989) contains further information on computer communications. Given these categories, I then turned to finding instances of those acknowledgement categories in human communication.

3. Applying The Acknowledgement Taxonomy to Human Communication

Positive acknowledgements are as easy to spot as recognizing "Yes" and "Ok". Negative acknowledgements are equally easy; "No", "I don't understand." and similar utterances are clearly negative acknowledgements. Delayed acknowledgements are seen in the fact that humans do not acknowledge everything right away, but can delay in reacting long enough to cause the communicator to recognize a lack of the expected response, and perhaps get triggered into repeating or rephrasing. Lost acknowledgements can arise because of distraction of the speaker--external or internal interference--and can also require communication repair with sentences such as "I'm sorry, did you say you wanted milk in your coffee?" Subsumed acknowledgement is seen in the fact that humans don't typically try to acknowledge every bit of the communication flow, but will periodically issue an acknowledgement that is understood to indicate an acknowledgement of all the communication since the previous acknowledgment was issued. In normal circumstances we expect the other party to understand what we are attempting to communicate, and do not require immediate and constant acknowledgement, but as the amount of time since the last acknowledgement increases, the communicator gets more and more worried. This is partially alleviated by the link keep-alive signal, such as what occurs in telephone conversations when one party will be heard issuing a stream of "Yes", "Right", "Uh-huh" and such. (I have timed various people who issue these types of back-channel acknowledgements at the rate of 20 or more times per minute). The request for acknowledgement shows up in sentences like "Did you hear me, Johnny?" or "Do you follow?". Flow control is observed in sentences such as "Slow down, you're not making sense." and "Look, I'm in a hurry. Would you please get to the point." Protocol negotiation arises when there is a need for accurate communication, as expressed by "Tell me when you don't understand, ok?". Dynamic link quality adjustment occurs naturally as the listener increases the frequency of positive acknowledgements and thus encourages the speaker to progress both faster and with more confidence. Lastly, error correction is simple and comprises statements like "I said 'Jane has a buyer.', not 'a tire'" or repeats back a serial number to ensure that the information was received correctly.

4. Communication Between Peer Processing Layers

The study of another aspect of computer network acknowledgements proved equally illuminating. Computer communication is typically modelled in terms of a hierarchy of seven layers. The acknowledgements take place between a specific layer on one machine and the corresponding layer on the other machine. All communication is done by packaging the information and handing it to the next lower layer, which encapsulates it and hands it down to the next lower layer, until it reaches the bottom or physical layer. From there it is transmitted to the physical layer of the destination machine, and the information moves up through the layers of processing until it reaches the layer that is a peer of the originating layer. Each layer has a different sphere of communication responsibility and ensures communication with its peer layers on other machines. As part of the communications protocol, there is no confusion about the intended destination layer since that is explicitly indicated as part of the contents of each data unit.

5. Communication Between Processing Layers In Human Communication

Part of what makes this study so interesting is that human communication is characterized by a similar set of layers of communication processing. At the lowest layers we have auditory or visual stimuli that require processing and categorization into low-level units of meaning, perhaps phonemes or roman characters. A higher level combines these elementary units into higher-level lexical units, or words. Above this the words are structured into phrasal units through syntactic parsing mechanisms, and pass the results on for semantic processing. These results are then sent on for pragmatic and other processing. Unlike communication layers within computers, these layers in humans do not necessarily hand received information up from layer to layer like a bucket brigade--they may run in parallel--but the similarities may shed more light on human communication.

The parallelism in multi-layer processing between the computer and human communication is striking. It is not surprising that one also finds parallel inter-layer acknowledgement mechanisms. The lowest layer acknowledgements are primarily various forms of negative acknowledgement; humans--and to a lesser degree, computers too--do not spend their time explicitly notifying the communicator that phonemes or other low-level units are being clearly and accurately identified, though there is a certain amount of back-channel "keep-it-coming" communication. Humans and computers do, however, quickly notifying the other party when these low-level units are not being correctly received or are not capable of being processed. At a higher level, humans are more likely to generate positive acknowledgements such as "Yes, you're absolutely right." or "Please tell me more." As the targeted acknowledgement layer gets higher, there is a more even mix of negative and positive acknowledgments.

One marked difference between computer and human communication in general--and acknowledgements in particular--is that in computer communicating layers are unambiguously identified and layers communicate only with peers on other machines, while in human communication the layers are not usually explicitly identified and confusion can arise over which layer was intended as the recipient of a particular communication. For instance, a student is asked to make a prediction, makes the prediction, is told "Ok, continue.", continues in the belief that the prediction was correct, and is later told that the statement was in fact incorrect. Drawing on the power of the analogical model, an explanation is clear: the "Ok, continue." was not intended as a judgement that the statement in question was accurate, but as an indication that the prediction had been understood and that the student was to proceed to develop the line of reasoning. The student understood the acknowledgement to be a judgement that the prediction was in fact correct, as opposed to what the acknowledgement was actually intended to convey. It is my belief that many examples of human miscommunication can be accounted for by this phenomenon of incorrectly concluding which processing layer a particular acknowledgment was targeted at.

6. Conclusions

This parallelism between acknowledgements in computer communication and acknowledgements in human communication appears to provide some measure of explanatory power, and it does not

appear to be a forced comparison, but seems instead natural and self-evident. This supports the belief that this particular interdisciplinary study is valid and useful.

The development of a taxonomy of acknowledgements helps guide the markup of our corpus of human dialog transcripts by providing a clearer picture of the possible mechanisms that could be in action at a given point in a communication session. A better understanding of acknowledgement categories also provides deeper insight into the tutor's and student's strategies and states of mind as reflected by the recorded transcripts; this is important to enhancing the instructional planner and student plan recognition mechanisms. Another possible beneficiary is the input analysis subsystem, which can benefit from an enhanced ability to pick up on any acknowledgement-born hints about the intended destination processing layer; this could make a difference in syntactic, semantic, and higher processing. Lastly, this study can assist in the process of discourse management and dialog generation by providing a deeper understanding of the acknowledgements that CIRCSIM-Tutor's users might expect and benefit from receiving, as well as a guide to what might not be acceptable from a machine.

The purpose of this paper was to explore the viability of one unusual source of information on human communication. This work in developing a taxonomy of acknowledgements is obviously not final; much more study of computer communications, the corpus, and other related areas--such as anthropological linguistics--is needed before a firmer taxonomy can be proposed.

7. Acknowledgements

This research took place at the Illinois Institute of Technology as part of the CIRCSIM-Tutor project. I owe much to my advisor, Martha W. Evens for her guidance, to the research team which has made CIRCSIM-Tutor a reality and continues to improve it, and to the Office of Naval Research for supporting our research. My thanks also to the reviewers, who helped make this a better paper.

References

Tanenbaum, Andrew S. (1989). Computer Networks. 2nd edition. Englewood Cliffs: Prentice-Hall.