Logics of communication and knowledge
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In this thesis I have studied the evolution of knowledge during communication between agents from a logical viewpoint. The great number of different perspectives I take in the different chapters show that there are many forms of communication. I mostly focussed on one-way communication through messages but even within this framework there are a lot of differences. This becomes very clear in Chapter 4. There, I give a very general approach in which many forms of communication can be modeled by adapting the model to the needs of the situation at hand. Several types of communicative actions can be defined, each with its own parameters, and every combination of parameters gives its own results in terms of knowledge evolution. I also give a clear definition of the network over which the agents communicate. The network can even be changed during the process of communication with a special action. It would be an interesting line of future research to see how this communication network can be incorporated in the approaches presented in the other chapters, which are more tailored to specific forms of communication. For example, in Chapters 5 and 6, which focus on email communication specifically, one could imagine the existence of certain “mailing lists” through which certain groups of agents can receive one shared email, while other agents can only be reached individually. Also, some agents may not know the email address of other agents, preventing them from contacting these agents directly. Then they might send their email to some third agent of which they do have the email address so this third agent can forward the message to the intended recipient.

Another potential topic of further work is to combine the concept of common knowledge discussed in Chapter 5 with the concepts of potential and definitive knowledge from Chapter 6. Such a study could start out with interpreting common knowledge under the assumption that everyone reads their messages immediately to arrive at “possible common knowledge” or under the assumption that everyone has only read email that they replied to in order to define “definitive common knowledge”. But more complicated extensions are also possible, for ex-
ample one where the “reading behaviour” varies between agents. Then one could assume that there is one group of agents who always reads their email, and another group who can only be counted upon to have read emails they replied to. This could even lead to nested expressions like “it is possible common knowledge in group A that it is definitive common knowledge in group B that this message was sent”. Continuing this line of thought, another interesting extension would be to investigate more kinds of reading behaviour than just “read everything immediately” or “read only what you reply to”.

It is also promising to investigate whether one could extend the contents of the messages discussed in Chapters 6 and 5 to formulas rather than basic notes. This can be extremely powerful, especially if these formulas also contain epistemic operators. Then the agents could send each other emails containing information like “Alice knows about this message, but Bob does not know she knows it”. It would require an intricate system of processing new information received by the agents. Such an approach would essentially combine and extend the strengths of Chapters 6 and 5 on the one hand and Chapter 3 on the other. In that chapter, the messages do contain formulas. These formulas do not contain epistemic operators, but because they can contain previous messages the language is already quite expressive. However, the downside of this approach is that the number of messages available to the agents must be limited to a finite set, which makes the set-up less general. It is still very suitable for many applications where a fixed protocol is being followed and it is also very relevant to many topics in game theory. If the limitation on the possible messages would be lifted this would result in a model of infinite size. This is essentially what happens in Chapter 5, where the complete model of all possible states is indeed infinite and therefore not represented explicitly. The model presented there is still a very nice theoretical representation, which allows for logical reasoning about the knowledge of the agents, in particular the common knowledge of a group of agents. However, I have not found a decision procedure for that model. This open question is solved for the framework presented in Chapter 6. There, the number of possible states is still infinite, but I have found a limit on the states that need to be evaluated in order to determine whether an agent knows something. This is a good solution for the problem of the infinite number of states. However, a finite model would allow for a better representation of the models in a way that is easy to understand for humans.

Another important open question concerns the work presented in Chapter 7. There, I present a notion of action emulation which is a relation between action models, meant to characterize their equivalence. For canonical action models, it does. For non-canonical action models, action emulation implies equivalence but it is yet unclear whether the converse is also true. Therefore, the open question is: does action model equivalence imply action emulation for non-canonical action models? If this holds then the notion of action emulation I presented is truly a new standard for action model equivalence. So far, I have found neither a proof
nor a counterexample.

In Chapter 8 I have studied the difference between knowledge and belief. I showed how knowledge relations in a model such as the ones used in Chapter 3 can be adapted to belief relations, and what consequences this has on the conditions we should impose on these relations. I also propose a new condition, that leads to the possibility to model a number of different kinds of belief. It would be interesting to combine this with the approach from Chapter 3 to a logic of messages and belief. One way to do this would be to give every message some “level of credibility” that determines how strongly the other agents believe its contents. This level of credibility might vary between the different agents depending on how prone they are to believe the message. It would be a big next step in epistemic logic to use a quantitative approach here, allowing one to compute for every agent the probability he gives to every possible event.

Such an approach would also be very relevant to Chapter 9, where I study the logic of lying. In this chapter I show how the act of telling a lie can be modeled as the manipulative update of an epistemic model. Furthermore, I study a game of Liar’s Dice where the players may either speak the truth or lie as a part of their strategy to win the game. Probabilities play a big role there because both opponents want to maximize their expected profit after a number of rounds of the game. Therefore, a probabilistic approach is indeed very promising.