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Negotiation using Commitment and Dialogue

by

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aos meus pais

(to my parents)

Quem não se comunica se trumbica!

Chacrinha - *O Velho Guerreiro*

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Abstract

The aim of this work is to show how computational models can be applied to solving problems that require negotiation, i.e. situations where parties confer with a view to compromise or agreement.

Our approach is based on argumentation, which is the use of debate and methodical reasoning for solving conflicts. We believe that a dialogic framework is suitable for capturing and representing some of the relevant features of argumentation, especially the interaction mechanisms embedded in it.

A logic presentation was selected as a means for representing our computational models. Logics and argumentation enjoy a close relationship that dates back to Aristotle.

We propose the use of a dialogic framework as a means for solving conflicts among parties. Hamblin has a formalism for the analysis of dialogue - which was extended by Mackenzie - that is a sound starting-point. It is based on the notions of legality and commitment. Each party of the dialogue has a commitment store where its own state of affairs is being registered and updated through a conjunction of commitments.

We introduce part of this dialogue formalism through issues in software engineering that could be addressed as negotiation problems. In particular, we apply it to software specification. In our example, the development of specifications is presented as a dialogue in which the parties negotiate, establish responsibilities and cooperatively validate and solve inconsistencies between themselves.

Based on this formalism, we build our framework. It develops into a two-tiered system comprising a Commitment Calculus (CC) and a Commitment Action Dialogue Reasoning System (CADReS).

We start by looking at the way that deontic logic dealt with the notion of commitment. Based on this we try to develop a commitment logic. This

logic fails to capture the *delayed realisation* aspect that we attribute to commitments. We move to a commitment calculus using a membership semantics. This time we approach the notion of commitment from the *awareness* point of view, preserving some of the important features of the deontic approach previously tried.

CADReS has axioms of the form $\{Pre \rightarrow [Party_A to Party_B, Locutions] Post\}$, where *Party_A* and *Party_B* are the participants in the dialogue and *Locutions* are the application of a finite set of locution modifiers to statements. *Pre* and *Post* are the pre- and post-conditions of the locutions performed by the party. The commitment calculus developed is used for the management and description of these conditions.

The framework for dialogue reasoning systems proposed, is suitable for representing some of the negotiation aspects characteristic of cooperative work. We do not provide negotiation strategies for manipulating the system.

Finally we revisit the software specification example using the representation scheme provided by the framework.

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Chapter 1

Introduction

The Industrial Revolution introduced drastic changes into the work place. Craftsmanship gradually lost its importance and the fragmentation of skilled jobs into very simple tasks became the synonym of progress. Taylorism was the doctrine that embodied these new ideas, and the new assembly lines at Ford car manufacture plants were their showrooms. As a result of this, factory workers began to perform repetitive non-specialised tasks and to behave like robots, which ultimately took over from the human being in the assembly lines.

Scientific activity in the western world had to be expanded in order to cope with the demand generated by this new industrial attitude. There was a necessity for new materials, techniques and social policies etc. In exchange, the scientific community got access to new instruments, installations and facilities etc. However, the all encompassing aspects of science were steadily neglected. Scientists were urged to achieve more immediate results and because of that became more and more restricted to smaller fields of research. Specialisation was promoted to a saturation point.

The far-reaching effects of industrial technology gave a major boost to issues like pollution and energy conservation, and also brought great advances in terms of transport and communications. Somehow, the all encompassing aspects of science mentioned above, became of paramount importance again.

The complexity of the problems and tasks, and the variety of skills needed to deal with them, currently facing industry and other forms of human organization, seems to be forcing the scientists out of their isolation, to shop around for ideas, concepts, techniques and methodologies etc, in other scientific fields. Science is talking to science in an interdisciplinary way. The latter has promoted the need for better structured and organized communication. Computers and its sister technologies are being used as the means for providing this environment.

Computer-Supported Cooperative Work (CSCW) emerged as a recognized research field, which intends to study the roles and working relationships among groups of people and groups of computer systems. Irene Greif (1988) presents us with a book of readings, which is a fair and comprehensive picture of the subject as it then stood. The book is divided into three parts. In the first part we are introduced to the pioneers and to the technologies - e-mail, teleconferencing, and office information systems - that emerged from their ideas. The second part of the book is dedicated to the new technologies being developed for CSCW. There are reports about systems being used to support asynchronous and synchronous meetings, together with articles about Hypertext, data sharing issues like co-authorship and multimedia systems. The third part of the book discloses CSCW's new design theories, putting forward recently developed methodologies and theoretical perspectives that will serve as guidance for the fascinating work that has yet to come.

Among all the articles from the aforementioned book, we would like to single out Winograd's *A Language/Action Perspective on the Design of Cooperative Work* (1988). It reports on the 'conversation manager' of The Coordinator,

'a first-generation conversational system currently used for everyday communications in sales, finance, general management, operations, and planning functions in organizations of a variety of sizes and types'.

The underlying theoretical approach is that

'conversations for actions are the central coordinating structure for human organizations. We work together by making commitments so that we can successfully anticipate the actions of others and coordinate them with our own....In applying this to computer system design, we are not concerned with duplicating the knowledge or thought patterns of people, but with the structure of their interactions and the embedding of those interactions in computer systems....Let people do the interpretation of natural language, and let the program deal with the explicit declarations of structure'.

We also agree that the interactional aspects of language are a sound common basis for the structuring and coordination of cooperative relationship among groups of people and groups of computer systems. People talking to people is by far the best way of establishing common ground, working together, negotiating contracts and solving conflicts. We believe that computerised conversational working environments are going to be extended and improved in such a way that soon it will be normal practice to see people *talking* to computer systems, computer systems *talking* to people and computer systems *talking* to computer systems. This is neither to be seen as the use of speech nor the use of natural language, but we are interested in the usage of conversation primitives to guide this process.

But we would like to go even further, extending the conversational framework for the outer circle of communication among groups of people and groups of computer systems to a dialogic framework for the inner circle of reasoning, fundamental to the performance of each of these agents' tasks. In order to bridge the gap between these two circles we should first point out the strong relationship between logics and formal reasoning and to the importance of logics for the programming of computer systems nowadays. Then, we should remind the careful reader that logics and dialectics, literally originated from the works of the very same Aristotle. For reasons that fall outside the scope of this dissertation, dialectics was associated with rhetoric which in its turn was associated with bad argumentation practices. We understand that today we are prepared enough, in terms of theoretical results and in machinery, to reassess dialectics and to use it as a sound framework

for automated reasoning and communication.

We are advancing the use of dialectics in computer science. The interdisciplinary flavour of this work is given by the interactions of disciplines like computer science, logic and philosophy etc, embedded in it. We think that science is going to increasingly become a team activity conducted as an interdisciplinary and cooperative enterprise.

Below we present the thesis that will guide us throughout this dissertation.

There is more to reasoning than the traditional view of logic. It is sensible to explore and apply other forms of reasoning to problems normally treated with deductive logic. An interesting example is negotiation. Dialectical reasoning is better suited to giving an understanding to this class of problems.

A dialogue formalism based on commitment and legality has been developed by Hamblin and extended by Mackenzie. It provides a framework within which logic can be seen as a discipline concerned with arguments and not only with proofs and derivations. To deal with the problem of negotiation, we have modified and recasted this framework and applied it to dialectical reasoning in computing. We have introduced part of this dialogue formalism through issues in software engineering that could be addressed as negotiation problems. In particular, we apply it to software specification.

Having motivated the use of dialectical reasoning in computing, we now look in more detail at commitment and legality, in order to provide a computational model of it. To do this, it is necessary to make explicit the consequences of reasoning using commitments. We start by looking at the way that deontic logic dealt with the notion of commitment. Based on this discussion, we try to develop a commitment logic. This logic fails to capture the *delayed realisation* aspect that we attribute to commitments. We move to a commitment calculus using a membership semantics. This time we approach the notion of commitment from the *awareness* point of view, preserving some of the

important features of the deontic approach previously tried.

The commitment calculus however, gives only a static view of commitment. We therefore embed this calculus into a dialogue system which gives a dynamic view of the way that commitments are established and discharged.

The software specification case is revisited using the representation scheme provided by the dialogue system.

We conclude that the dialogue system captures some of the relevant features of dialectical reasoning and that a satisfactory computational model of dialectical reasoning can be built. Therefore we believe that the system outlined, is suitable for representing some of the negotiation aspects characteristic of cooperative work. We intend in the future to use this approach to deal with problems of cooperative and group work.

1.1. General Overview

This work is divided into two parts: Dialectical Reasoning and A Framework for Dialogue Reasoning System.

Chapter 2 argues that, although analytical reasoning dominates the scene among the computing community involved in artificial intelligence, other forms of reasoning should also be taken into consideration. We make the case for dialectical reasoning. Our motivation comes from problems that require the use of negotiation for their solution. Our approach is based on argumentation.

The use of a dialogic framework as a basis for solving conflicts among parties is proposed in chapter 3. We briefly survey the field and give the reasons for choosing Hamblin's formalism for the analysis of dialogue as our starting-point. We stimulate the use of this framework applied to situations where cooperation and conflict are of paramount importance. The example that we use comes from software specification. It is a *cooked* one which does not address the natural

language aspects of the field.

Up to this point, we will have been introducing the dialogue formalism and also proposing the use of dialectical reasoning when dealing with problems that require the use of negotiation for their solution. This constitutes the first part of the dissertation. The second part puts forward a framework for dialogue reasoning systems which embodies the dialogic framework that was introduced in the first part. But first we have to develop some formalism to capture the notion of commitment which is crucial to the framework.

Chapter 4 starts by looking at the way that deontic logic dealt with the notion of commitment. Based on this discussion, we try to develop a commitment logic. This logic fails to resolve the paradoxes inherited from deontic logic and is also unable to capture the *delayed realisation* aspect that we attribute to commitments.

Chapter 5 revisits the notion of commitment approaching it this time from the awareness point of view. Commitment also plays a role in the interaction process, which enables successful cooperation and conflict resolution among different parties to take place. We conclude the chapter by putting forward a framework for dialogue reasoning systems divided into a static part - the Commitment Calculus (CC) and a dynamic part - a Commitment Action Dialogue Reasoning System (CADReS).

A commitment calculus is developed in chapter 6. It is based on the notion of commitment advanced in the previous chapter. This calculus is for dealing with the consequences of having commitments. It only gives a static view of commitment.

A Commitment Action Dialogue Reasoning System, which gives a dynamic view of the way that commitments are established and discharged is outlined in chapter 7. CADReS is described in an axiomatic way. For each locution modifier we provide a list of commitment and legality axioms. We show that the dialogue reasoning system outlined, is suitable for representing some of the negotiation aspects characteristic of cooperative work. We do not provide a fully

worked out automated system.

Chapter 8 revisits the software specification case using the representation scheme provided by CADReS.

Chapter 9 attempts an evaluation of the main achievements of the thesis, and suggests directions for further research.

1.2. About the Work

This dissertation was written using normal word processing applications. The pictures presented in the thesis are just for illustrational purposes. There is no animation of the framework by any software environment or tool which is used in this thesis.

In the bibliography at the end of this dissertation there are four entries for joint work involving the author. Two of them play no role or a minor role in the making of this thesis: *How to Prove Theorems using Dialogue* (Fuks, Pequeno & Sadler) and *Conversation Analysis and Specification* (Finkelstein & Fuks).

Multi-party Specification (Finkelstein & Fuks) and chapter 3 *A Dialogic Framework* overlap. The author's contribution to the paper was the research concerning Hamblin's and Mackenzie's work and the tailoring and application (the last being shared with the co-author) of the rules to the examples. The author was not involved in the implementation of any of the software tools mentioned in the paper.

Outline of a Commitment Logic for Legal Reasoning (Fuks, Ryan & Sadler) and chapter 4 *Deontic Commitment* overlap. The author's contribution to the paper was the research concerning deontic logic, the specification of the commitment logic and the examples. The design of the rules was shared with the co-authors.

There is no need to read any of these papers to properly understand the work developed in thesis.

PART I

Dialectical Reasoning

Chapter 2

Negotiation

Negotiation permeates many aspects of our everyday life. Normally, the accomplishment of a task involving more than one party is by means of agreements, commitments and compromises.

2.1. Forms of Reasoning

Logic or reasoning has recorded origins dating back to the time of Aristotle. He divides it into two basic forms: analytical and dialectical. The former deals with necessary and the latter with probable reasoning.

The turn of the century saw some major transformations in so-called modern logic. Formal deductive logic has developed to the extent of becoming one of the major trends in computational models for reasoning. Unfortunately, other forms of reasoning not strictly identified with formal deductive logic were neglected.

However, artificial intelligence or more precisely expert systems, need in their ever increasing development, broader ways of dealing with the phenomenon of language, an area where the various traditions of modern logic fail to make ground. Very encouraging is the emergence of a community of philosophers, mathematicians and logicians that see

language as the prime matter of thought. Their inspiration comes mainly from the writings of L. Wittgenstein. They are concerned with what a proposition is - not just whatever is true or false - especially regarding its two main aspects, namely the conditions for assertion and the use of connectives. By demonstrating the non-existence of coherent criteria for laying down these two main aspects of a proposition, they signal the doom of the traditional way of looking at semantics - object and designation, the *pièce de résistance* of classical logic (de Queiroz 1988).

Far from going back to Aristotle's view of logic, we are concerned with reestablishing logic's broadest relationship to reasoning; not just to analytical reasoning. First we identify three different forms of reasoning:

- i) Analytical reasoning: It is the form of reasoning that conforms to the laws of formal logic. The notion of *truth* prevails here. Results can be demonstrated, i. e. calculated in accordance with rules that have been laid down in advance.
- ii) Dialectical reasoning: It is founded on opinion and concerned with contingent realities. It is not *formally* valid but it is only reasonable or probable. It is founded on agreement. It conforms to the laws of interaction and minimum or immediate consistency preservation. The parties involved make concessions and commitments to achieve a *satisfactory* mid-term position.
- iii) Oratorical reasoning: In this sort of reasoning the parties present their cases, leaving the decision to a third party. It presupposes the existence of a *tertius* for harmonising conflicting views.

One could consider examining each of these three forms of reasoning on the basis of the qualitative aspects of the number of parties involved.

Analytical reasoning is related to one party, the dialectical form is related to two parties and the oratorical form is related to three parties.

We are not trying to say that with only one party we ought to have analytical reasoning and so on. After all, it is not uncommon to find one *dialoguing* with oneself for solving various inner conflicts, simulating in this way a dialectical form of reasoning. Sometimes one has as a last resort what one heard from a parental, public or religious figure, simulating in that way an oratorical form of reasoning. The same applies to dialectical and oratorical reasoning not being necessarily performed by two or three parties, respectively. For the sake of simplicity though, we are going to relate the analytical, dialectical and oratorical forms to the involvement of one, two or three parties in the process of reasoning.

2.2. Argumentation

Logics, 'considered in its most meaningful nucleus - which is the theory of deduction' (Ladriere 1989) - and argumentation relate to statements - propositions - in an opposite, but not conflicting way. While deduction guarantees the passing of *truth* from a collection of statements - premises - to those statements - conclusions - that follow from it, argumentation traverses back along this *path* providing justification for the conclusions by making the premises available.

Metaphorically speaking, this *path* could be seen as a river of *implications* where deduction flows downstream while argumentation zigzags upstream.

Negotiation seems to zigzag more than flow. It also comes closer to argumentation for scarcely making use of the notion of *truth*. During the negotiation process one is busier in giving support to one's views of the subject than concluding things about it, especially if one understands negotiation as the process of compromising and reaching agreement.

We propose the use of dialectical reasoning as a course of action for negotiation. Argumentation epitomizes it, being the use of debate and methodical reasoning for solving conflicts. We believe that a dialogic framework is suitable for capturing the relevant features of argumentation, especially the interaction mechanisms embedded in it.

A framework for dialogue reasoning systems is proposed as a means for representing some of the negotiation aspects characteristic of cooperative work. An action logic presentation is chosen for its ability to talk about actions, which is paramount for making the interactional aspects of the negotiation process explicit. This way we are able to talk about straightforward things like questions and answers, which is not easy to do with other logic presentations.

Concerning the modelling of each party's range of information about the dialogue, we are more interested in developing a *calculus* for dealing with the interaction process between different parties' actions - a pragmatic approach, rather than simulating their thinking process - a psychological approach. While the latter asks for a highly specialized theory of belief, the former seeks a much simpler set of rules for coordination and conflict resolution among different parties' interests. 'We work together by making commitments so we can successfully anticipate the actions of others and coordinate them with our own' (Winograd 1988). The notion of commitment seems to embody the visible aspects involved in the negotiation process. Finally, Hamblin (1987) bonds the notions of commitment and belief: "In short, the concept of belief is an idealization of that of indicative commitment."

Chapter 3

A Dialogic Framework

In the previous chapter we proposed the use of a dialogic framework as a platform for negotiation to solve conflicts among parties. Chapter 3 briefly surveys the field and introduces part of the chosen formalism through examples originating from software specification.

3.1. Survey

The underlying vehicle for defining our framework is a formal account of dialogue. Such accounts have their roots in a number of different traditions:

the *game theoretic semantics tradition* in which "dialogue games" are used to define the meanings of components of a formal language, for example Lorenz (1982);

the *foundations of logic tradition* in which an understanding of the communicative context of argument is examined to understand the development of different logical traditions, notably Hamblin (1971);

the *human computer interaction tradition* in which representations of dialogues are developed for design and evaluation of user interfaces, for example Schneiderman (1982) and Green (1983);

the *rhetorical or argumentative tradition* in which a model of dialogue

provides the normative base for deciding what constitutes rhetorical "competence", for example Allwood (1986);

the *natural language processing tradition* in which computationally tractable models are sought to provide a basis for automatically interpreting and generating dialogues, for example Carbonell (1982);

the *distributed artificial intelligence tradition* in which computational models of multi-agent "negotiation" are constructed to integrate diverse knowledge sources, notably Erman & Lesser (1975), Smith (1980), Smith & Davis (1981), Kornfeld & Hewitt (1981) and Lenat (1975).

We have sought to combine the formal apparatus - dialogue formalism - of the foundations of logic tradition with the approach - cooperation and negotiation - of the distributed artificial intelligence tradition. We have explicitly rejected the competitive approach typical of the game theoretic semantics tradition and are not directly concerned with the discourse level issues that dominate both the natural language processing and the rhetorical tradition. The descriptive tools provided by the human computer interaction tradition lack the required expressiveness for the less highly constrained dialogues on which we have focussed.

3.2. Hamblin's Formalism

Hamblin's formalism for the analysis of dialogue is based on the notions of legality - as a means of providing the dialogue with etiquette - and commitment. Each party of the dialogue has a commitment store where its own state of affairs is being registered and updated through a conjunction of commitments.

Mackenzie (1979a, 79b, 80, 81, 84) extended this formalism with systems DT, DC, DD and DC+. We have adopted his dialogue system DC as the basis for the design of a dialogic framework - with a strong cooperative flavour - for negotiation. In the examples that follow, DC is introduced using our own notation and with modifications that are spelled out. The basic concepts nevertheless, were preserved. We strongly recommend

the interested reader to consult Mackenzie's works cited in this dissertation's bibliography.

3.3. Introducing the Formalism

Firstly the author would like to acknowledge his joint paper *How to Prove Theorems using Dialogue* (Fuks, Pequeno & Sadler 1988) in which there is a first attempt to apply the dialogue formalism to the outline of a fragment of the theorem prover described in Gabbay and Reyle (1984) and Gabbay (1985). The former does not play a role in this thesis.

We introduce the dialogue formalism through examples originating from software specification. In the examples, we have tried to capture in a very idealised way the conventional setting of requirements specification in which clients and systems analysts sit around a table - the clients explaining the requirements, waving documents in the air and occasionally arguing among themselves while the developers ask guiding questions, seek clarification, point out inconsistencies and raise unanticipated consequences.

3.3.1. Negotiating Software Specification

Human organizations, being based on team activity, strongly rely upon negotiation. The process of software specification exemplifies this kind of activity. We see the development of a specification as a dialogue in which the parties negotiate, establish responsibilities and cooperatively construct an overall specification. The term dialogue, as generally used, refers to a conversation or spoken interaction between two parties.

In this section we apply the dialogic framework to enable a few short dialogues to take place between two parties. Each has differing perspectives on, and knowledge about, the object system, as well as a variety of skills, roles and so on. In some cases the perspectives may be based on underlying contradictions. To construct a specification the parties must cooperate; that is, contribute to the achievement of a joint

understanding. This contrasts with the approach taken by existing specification schemes, methods and tools which are generally based on specification from a single party's point of view.

Below we briefly introduce the context within which our examples are developed.

A party is a *logical* participant in the dialogue. We can loosely define a party as an agent responsible for maintaining a particular perspective. A physical participant in a dialogue may *act the part of* or *represent* many logical parties. For example, a librarian might be responsible for both acquisitions policy and disposals.

Each party has a commitment store which holds its commitments within the dialogue. A commitment is the public engagement to a statement that restricts freedom of action. A commitment to a statement is, in effect, holding yourself out as liable for the consequences of that statement (just as clients in *real-life* software specification *commit* themselves by signing off a requirements statement). As a concept commitment needs to be carefully distinguished from epistemic notions such as belief, which are essentially private and which we exclude from our model both on philosophical and technical grounds. The general status and role of commitments is discussed by Winograd & Flores (1986). In the context of design Thimbleby (1988) suggests that '... abstraction and commitment are inverse processes - an abstraction is an outcome of relaxing commitments and a representation is the outcome of making commitments'.

The contents of the commitment store of each party changes as the dialogue progresses. A party can read from any store. The only way it can alter the commitments of any party, including its own, is through participation in the dialogue. A specification is the pool of commitments that result from such a dialogue.

Each party has a working area which is its private *sketch-pad* or database. It contains the internal or working statements which do not

have the full status of public engagement. No other party can directly access the working area without permission nor is there any obligation for the party to maintain its consistency. (Notationally: $WA_a \Rightarrow$ Party_A's working area and $WA_b \Rightarrow$ Party_B's working area.)

The dialogue scheme is presented in terms of three important constructs:

(i) Locutions

Consist of a statement and a modifier, represented as **locution modifier**(Statement). Statements are constructed in a propositional language which includes negation, conditional, disjunction and conjunction of statements. 'Since our locution modifiers must be applied to statements, no problem of the iteration or interaction of locution modifiers arise here' (Mackenzie 1985). Locution modifiers are as follows:

Assertions, to be read as "It is the case that Statement", notationally **asserts**(Statement).

Questions, to be read as "Is it the case that Statement?", notationally **questions**(Statement).

Withdrawals, to be read as "I am not sure that Statement", or "No commitment to Statement", notationally **withdraws**(Statement).

Challenges, to be read as "Why is it to be supposed that Statement" or "How is it known that Statement", notationally **why**(Statement).

Justifications, to be read as "Statement is a justification for the Challenge", notationally **justifies**(Statement).

Mackenzie does not have a specific locution modifier named justification. What Mackenzie calls 'an assertion given as a ground answer for a challenge' and what we call 'justification' above are one and the same thing. We believe that by isolating this particular instance

of 'assertion' - and calling it 'justification' - it is easier to represent the nature of the verbal exchanges that occur in a cooperative environment. (In the paper *Multi-party Specification*, we have used 'assertion' and not 'justification'.)

Denials, to be read as "I deny that it is the case that Statement", notationally **denies**(Statement).

Mackenzie (1985) does not grant denial the status of a locution modifier, because denial only occurs after questions. For reasons that are similar to those given to justification above, we are treating it as a locution modifier. Mackenzie does not provide us with a commitment rule for it, and this will be necessary for the example below.

Resolution demands, to be read as "Resolve this set of statements against this specific statement", notationally **resolve**(Set_of_Statements/Statement).

Resolution demand is a special locution modifier that is applied to a set of statements and not to a single one. Mackenzie (1985) presents it in two different forms: The first one R'T where 'T' is a set of statements and a second one R'T/s where 's' is a statement that seen together with 'T', indicates the existence of some sort of inconsistency inside the commitment store. We have stuck to the latter, because in a cooperative environment fleshing out the contradictions helps the parties to reach a consensus. (In the paper *Multi-party Specification*, we have opted for the other form of resolution demand.)

(ii) Dialogue Events

Represented by a triple of the form <Stage, Party, Locution>. Stage marks the progress of the dialogue: stage, stage+1 and so on. Party indicates the current speaker. A dialogue is a sequence of such events.

(iii) Commitments

Represented $C_{\text{party}}(\text{Stage, Statements}^*)$. Statement* is either Statement and/or **why**(Statement). This remark is important because of commitment rule Challenge below. Each party has a commitment store which holds its commitments within the dialogue. (Notationally: $C_s \Rightarrow$ Speaker's commitment store and $C_h \Rightarrow$ Hearer's commitment store.)

These constructs are used in the rules of the scheme which are divided into three subsets:

(i) Dialogue rules

Establish the *etiquette* or rules governing the legitimate shape of the interaction; they provide a way of maintaining a *legal* dialogue. For example:

Dialogue rule Question:

No legal dialogue of length stage+1 contains an event
 <stage-1,hearer,**questions**(Statement)>
 unless it also contains an event
 <stage,speaker,**asserts**(Statement)> or
 <stage,speaker,**withdraws**(Statement)> or
 <stage,speaker,**denies**(Statement)>.

After the questioning of a statement (**questions**(Statement)), the next event must be either the assertion (confirmation) of that statement, its withdrawal or its denial (**asserts**(Statement), **withdraws**(Statement) or **denies**(Statement)).

(ii) Commitment rules

Set out how locutions affect the commitment store of each party. For example:

Commitment rule Withdrawal:

After <stage,speaker,**withdraws**(Statement)>

$$C_s(\text{stage}+1, \text{Statements}^*) = C_s(\text{stage}, \text{Statements}^*) - \{\text{Statement}\}$$

$$C_h(\text{stage}+1, \text{Statements}^*) = C_h(\text{stage}, \text{Statements}^*) - \{\text{Statement}\}$$

After a withdrawal the statement is removed from the speaker's commitment store, the hearer's store remains unchanged.

(iii) Argument forms

Define, syntactically, the form of reasoning permissible within the dialogue and common to its participants. Our presentation of DC primarily involves *modus ponens*, though addition of other schemas to fit various logical tastes is possible. The argument form mechanism for *modus ponens* is embedded in the rule below:

Commitment rule Justification:

After <stage,speaker, **justifies**(AnotherStatement)>

where the preceding dialogue event was

<stage-1,hearer,**why**(Statement)>

$$C_s(\text{stage}+1, \text{Statements}^*) = C_s(\text{stage}, \text{Statements}^*) \cup$$

$$\{\text{AnotherStatement}, \text{AnotherStatement} \rightarrow \text{Statement}\}$$

$$C_h(\text{stage}+1, \text{Statements}^*) = C_h(\text{stage}, \text{Statements}^*) \cup$$

$$\{\text{AnotherStatement}, \text{AnotherStatement} \rightarrow \text{Statement}\}$$

After a justification (AnotherStatement) which occurs as a ground answer to a challenge (**why**(Statement)) both views are committed to the ground answer (AnotherStatement) and to the conditional (AnotherStatement $\rightarrow$ Statement).

As can be seen, not only was {AnotherStatement} added to both stores, as would be expected, but also {AnotherStatement $\rightarrow$ Statement}. If we take {AnotherStatement, AnotherStatement $\rightarrow$ Statement} and apply the *modus ponens* rule to it, we deduce {Statement} - exactly what was originally challenged.

The following examples show how the framework can be applied to software specification. It is a small case study concerning description of an automated travel ticketing system. In this case study various statements about travel and travel discounts are distributed between the working areas of two parties.

3.3.1.1. Example A

The working areas are:

WA_a: ticket→can_travel

WA_b: full_fare→ticket
 discount_fare→ticket
 discount_fare

This example illustrates the addition of information to a description. Let us follow what happens in the process of making this addition.

Initially the commitment stores are empty. The speaker (Party_B) asserts the statement, in this case *ticket* [*can obtain a ticket*] (an immediate consequence of the content of its working area (*discount_fare*, *discount_fare→ticket*) [*paid a discount fare* and *paying a discount fare implies that you can obtain a ticket*]), and so by:

Commitment rule Assertion:

After <stage,speaker,asserts(Statement)>

$$C_s(\text{stage}+1, \text{Statements}^*) = C_s(\text{stage}, \text{Statements}^*) \cup \{\text{Statement}\}$$

$$C_h(\text{stage}+1, \text{Statements}^*) = C_h(\text{stage}, \text{Statements}^*) \cup \{\text{Statement}\}$$

After the assertion of a statement the speaker and the hearer are both obliged to place that statement in their commitment store.

The rule Assertion defines an important feature of this dialogue scheme. A party is committed to anything stated by another party. The placing of the statement inside the hearer's commitment store is a way

to force him to react to it. If he agrees with it, he becomes committed to it and to its immediate consequences. The notion of immediacy can be partly exemplified by the derivation of 's' from 'T' using modus ponens only once. If he does not agree with it and wants to remove it from his commitment store, this can only be done by a subsequent withdrawal or challenge.

The resulting commitment stores are $C_a(1,(\text{ticket}))$ and $C_b(1,(\text{ticket}))$. Both Party_A and Party_B are committed to *ticket* and must answer for any immediate consequences of this commitment and other commitments added in a similar manner.

3.3.1.2. Example B

The working areas are:

WA_a: child→member_of_public
 oap→member_of_public
 commuter→member_of_public
 ¬member_of_public→member_of_staff
 ¬member_of_staff→member_of_public
 ¬oap and ¬child→commuter
 ¬commuter and ¬oap→child
 ¬child and ¬commuter→oap
 ticket→can_travel
 ¬commuter and ¬entitled_discount→¬can_travel

WA_b: full_fare→ticket
 discount_fare→ticket
 entitled_discount→discount_fare
 ¬entitled_discount→full_fare
 member_of_staff→entitled_discount
 oap→id_card
 child→id_card
 id_card→entitled_discount

Let us now consider a slightly more complicated example illustrating refinement of a description. We start at a point some way into a set of dialogues with $C_a(n, (child \rightarrow ticket))$ - Party_A's commitment store in the previous stage - containing a commitment to *child* $\rightarrow$ *ticket* [*a child can obtain a ticket*]. Party_A, the speaker and initiator of this part of the dialogue, asks something along the lines of *Why is it to be supposed that a child can obtain a ticket?*

It should be noted that in this setting asking why is a demand for evidence, not for an explanation. So by:

Commitment rule Challenge:

After $\langle stage, speaker, \mathbf{why}(\text{Statement}) \rangle$

$$C_s(stage+1, \text{Statements}^*) = C_s(stage, \text{Statements}^*) \cup \{\mathbf{why}(\text{Statement})\}$$

$$C_h(stage+1, \text{Statements}^*) = C_h(stage, \text{Statements}^*) \cup \{\text{Statement}\}$$

After a challenge the hearer adds the challenged statement to its own commitment store and the speaker removes the statement from its commitment store, replacing it by the challenge itself. This is part of the mechanism that is necessary to avoid the problem of circularity. (*Why is the book on loan?, Because it is out of the library!, Why is it out of the library?, Because it is on loan!* and so on).

The resulting commitment stores are:

$$C_a(n+1, (\mathbf{why}(child \rightarrow ticket)));$$

$$C_b(n+1, (child \rightarrow ticket)).$$

Party_B replies to maintain dialogue legality as indicated by:

Dialogue rule Turn-Taking:

No legal dialogue contains an event $\langle stage, given_party, locution \rangle$ if it also contains an event $\langle stage-1, given_party, locution \rangle$ or if locution is not properly constructed.

Each party contributes a locution at a time, in turn each locution must be well formed; that is an assertion, question, etc.

Next, *discount_fare* is given as a justification for the challenge. It is taken from the statement contained in the working area that *discount_fare* $\rightarrow$ *ticket*. The resulting commitment stores are derived according to the rule below:

Commitment rule JustIMP:

(Justification for the Challenge of an Implication):

After $\langle \text{stage}, \text{speaker}, \text{justIMP}(\text{AnotherStatement}) \rangle$

where the preceding dialogue event was

$\langle \text{stage-1}, \text{hearer}, \text{why}(\text{Statement1} \rightarrow \text{Statement2}) \rangle$

$C_s(\text{stage}+1, \text{Statements}^*) = C_s(\text{stage}, \text{Statements}^*) \cup$

$\{\text{AnotherStatement}, \text{AnotherStatement} \rightarrow \text{Statement2}\}$

$C_h(\text{stage}+1, \text{Statements}^*) = C_h(\text{stage}, \text{Statements}^*) \cup$

$\{\text{AnotherStatement}, \text{AnotherStatement} \rightarrow \text{Statement2}\}$

After an assertion (AnotherStatement) which occurs as a reply to a challenge (**why**(Statement1 $\rightarrow$ Statement2)) both parties are committed to the reply (AnotherStatement) and to the conditional (AnotherStatement $\rightarrow$ Statement2).

In effect, the rule above treats 'Statement1' as an assumption, and handles the reply to the challenge, as a justification for 'Statement2'. Mackenzie (1985) does not have this locution modifier. Our inspiration comes from the way Gabbay (1985) handles conditionals. (In the paper *Multi-party Specification*, we have used assertion and not justification.)

The resulting commitment stores are:

$C_a(n+2, (\text{why}(\text{child} \rightarrow \text{ticket}) \wedge \text{discount_fare} \wedge \text{discount_fare} \rightarrow \text{ticket}));$

$C_b(n+2, (\text{child} \rightarrow \text{ticket} \wedge \text{discount_fare} \wedge \text{discount_fare} \rightarrow \text{ticket})).$

The continuation of this dialogue generates the argumentation steps - making the premises available - required to show why a child can obtain a ticket.

Party_A can challenge either $discount_fare \rightarrow ticket$ or $discount_fare$. It chooses to challenge $discount_fare$ because what is there to be challenged is $child \rightarrow discount_fare$ [Why does $child$ imply $discount_fare$?]. Party_A is trying to establish the chain of reasoning that justifies $child \rightarrow discount_fare$. This illustrates Party_A's reasoning strategy, which is a topic that we are not going to deal within this dissertation.

Party_B checks his working area and **justifies**(entitled_discount).

The resulting commitment stores after these pair of dialogue events are:

$$C_a(n+4, (\mathbf{why}(child \rightarrow ticket) \wedge discount_fare \rightarrow ticket \wedge \mathbf{why}(discount_fare) \wedge entitled_discount \wedge entitled_discount \rightarrow discount_fare));$$

$$C_b(n+4, (child \rightarrow ticket \wedge discount_fare \wedge discount_fare \rightarrow ticket \wedge entitled_discount \wedge entitled_discount \rightarrow discount_fare)).$$

Party_A can challenge either $entitled_discount \rightarrow discount_fare$ or $entitled_discount$. It chooses to challenge $entitled_discount$ because what is there to be challenged is $child \rightarrow entitled_discount$ [Why does $child$ imply $entitled_discount$?].

The resulting commitment stores are:

$$C_a(n+5, (\mathbf{why}(child \rightarrow ticket) \wedge discount_fare \rightarrow ticket \wedge \mathbf{why}(discount_fare) \wedge entitled_discount \rightarrow discount_fare \wedge \mathbf{why}(entitled_discount)));$$

$$C_b(n+5, (child \rightarrow ticket \wedge discount_fare \wedge discount_fare \rightarrow ticket \wedge entitled_discount \wedge entitled_discount \rightarrow discount_fare)).$$

Party_B consults his working area and **justifies**(id_card).

The resulting commitment stores are:

$C_a(n+6, (\mathbf{why}(\text{child} \rightarrow \text{ticket}) \wedge \text{discount_fare} \rightarrow \text{ticket} \wedge$
 $\mathbf{why}(\text{discount_fare}) \wedge \text{entitled_discount} \rightarrow \text{discount_fare} \wedge$
 $\mathbf{why}(\text{entitled_discount}) \wedge \text{id_card} \wedge \text{id_card} \rightarrow \text{entitled_discount}));$
 $C_b(n+6, (\text{child} \rightarrow \text{ticket} \wedge \text{discount_fare} \wedge \text{discount_fare} \rightarrow \text{ticket} \wedge$
 $\text{entitled_discount} \wedge \text{entitled_discount} \rightarrow \text{discount_fare} \wedge \text{id_card} \wedge$
 $\text{id_card} \rightarrow \text{entitled_discount})).$

Party_A can challenge either $\text{id_card} \rightarrow \text{entitled_discount}$ or id_card .
 It chooses to challenge id_card because what is there to be challenged
 is $\text{child} \rightarrow \text{id_card}$ [*Why does child imply id_card?*].

The resulting commitment stores are:

$C_a(n+7, (\mathbf{why}(\text{child} \rightarrow \text{ticket}) \wedge \text{discount_fare} \rightarrow \text{ticket} \wedge$
 $\mathbf{why}(\text{discount_fare}) \wedge \text{entitled_discount} \rightarrow \text{discount_fare} \wedge$
 $\mathbf{why}(\text{entitled_discount}) \wedge \text{id_card} \rightarrow \text{entitled_discount} \wedge$
 $\mathbf{why}(\text{id_card}));$
 $C_b(n+7, (\text{child} \rightarrow \text{ticket} \wedge \text{discount_fare} \wedge \text{discount_fare} \rightarrow \text{ticket} \wedge$
 $\text{entitled_discount} \wedge \text{entitled_discount} \rightarrow \text{discount_fare} \wedge \text{id_card} \wedge$
 $\text{id_card} \rightarrow \text{entitled_discount})).$

Party_B checks his working area and **justifies**(child).

The resulting commitment stores are:

$C_a(n+8, (\mathbf{why}(\text{child} \rightarrow \text{ticket}) \wedge \text{discount_fare} \rightarrow \text{ticket} \wedge$
 $\mathbf{why}(\text{discount_fare}) \wedge \text{entitled_discount} \rightarrow \text{discount_fare} \wedge$
 $\mathbf{why}(\text{entitled_discount}) \wedge \text{id_card} \rightarrow \text{entitled_discount} \wedge$
 $\mathbf{why}(\text{id_card}));$
 $C_b(n+8, (\text{child} \rightarrow \text{ticket} \wedge \text{discount_fare} \wedge \text{discount_fare} \rightarrow \text{ticket} \wedge$
 $\text{entitled_discount} \wedge \text{entitled_discount} \rightarrow \text{discount_fare} \wedge \text{id_card} \wedge$
 $\text{id_card} \rightarrow \text{entitled_discount})).$

This example shows how this dialogue formalism provides us with the

means for representing the challenging-justifying mechanism - making the premisses available - which is common in cooperative work.

3.3.1.3. Example C

The working areas are:

WA_a: child→member_of_public
 oap→member_of_public
 commuter→member_of_public
 ¬member_of_public→member_of_staff
 ¬member_of_staff→member_of_public
 ¬oap and ¬child→commuter
 ¬commuter and ¬oap→child
 ¬child and ¬commuter→oap
 ticket→can_travel
 ¬commuter and ¬entitled_discount→¬can_travel
 id_card→entitled_discount
 ¬id_card
 oap→id_card
 oap

WA_b: full_fare→ticket
 discount_fare→ticket
 entitled_discount→discount_fare
 ¬entitled_discount→full_fare
 member_of_staff→entitled_discount
 oap→entitled_discount

The final example we will consider illustrates a number of features including progressive verification of one party with respect to another. By looking at WA_a above it should be easy to spot the inconsistency which has been introduced (*¬id_card*) [*It is not the case that there is an id_card*], as a result of which notice the inconsistency that may

possibly arise between Party_B (which is working on the basis of $oap \rightarrow entitled_discount$ [*Oap's are entitled to a discount*] and Party_A.

Party_B challenges $oap \rightarrow entitled_discount$. The resulting commitment stores, C_a and C_b are derived similarly to the previous examples.

The resulting commitment stores are:

$C_a(n+1, (oap \rightarrow entitled_discount));$
 $C_b(n+1, (\mathbf{why}(oap \rightarrow entitled_discount))).$

Party_B replies by asserting id_card obtained by matching with the implication $id_card \rightarrow entitled_discount$ and the commitments are established according to Commitment rule JustIMP (Justification for the Challenge of an Implication) which we have also seen before.

The resulting commitment stores are:

$C_a(n+2, (oap \rightarrow entitled_discount \wedge id_card \wedge$
 $id_card \rightarrow entitled_discount));$
 $C_b(n+2, (\mathbf{why}(oap \rightarrow entitled_discount) \wedge id_card \wedge$
 $id_card \rightarrow entitled_discount)).$

Party_B now challenges id_card and Party_A withdraws it being unable to deny it due to Dialogue rule Challenge which, substantially abbreviated, states:

Dialogue rule Challenge:

The reply to a challenged statement must be the withdrawal of the statement or it must be the resolution demand of an immediate consequence conditional of the statement whose consequent is the challenged statement and whose antecedent is a conjunction of statements to which the challenger is committed or it must be a statement to whose challenge the challenger is not committed.

The resulting commitment stores after these pair of dialogue events are:

$$C_a(n+4, (oap \rightarrow \text{entitled_discount} \wedge \text{id_card} \rightarrow \text{entitled_discount}));$$

$$C_b(n+4, (\mathbf{why}(oap \rightarrow \text{entitled_discount}) \wedge \text{id_card} \rightarrow \text{entitled_discount} \wedge \mathbf{why}(\text{id_card}))).$$

Next Party_B will force the construction of a chain of reasoning that will help both parties to verify if they both have the same understanding of the specification. Some straightforward questioning and answering follows with the results determined by Commitment rule Assertion above and:

Commitment rule Question:

After $\langle \text{stage}, \text{speaker}, \mathbf{questions}(\text{Statement}) \rangle$

$$C_s(\text{stage}+1, \text{Statements}^*) = C_s(\text{stage}, \text{Statements}^*)$$

$$C_h(\text{stage}+1, \text{Statements}^*) = C_h(\text{stage}, \text{Statements}^*)$$

Questions do not affect commitment stores.

Party_B **questions**($oap \rightarrow \text{id_card}$) and Party_A answer yes by replying **asserts**($oap \rightarrow \text{id_card}$).

The resulting commitment stores after these pair of dialogue events are:

$$C_a(n+6, (oap \rightarrow \text{entitled_discount} \wedge \text{id_card} \rightarrow \text{entitled_discount} \wedge oap \rightarrow \text{id_card}));$$

$$C_b(n+6, (\mathbf{why}(oap \rightarrow \text{entitled_discount}) \wedge \text{id_card} \rightarrow \text{entitled_discount} \wedge \mathbf{why}(\text{id_card}) \wedge oap \rightarrow \text{id_card})).$$

Party_B **questions**(oap) and Party_A confirms it by replying **asserts**(oap).

The resulting commitment stores after these pair of dialogue events are:

$$C_a(n+8, (oap \rightarrow \text{entitled_discount} \wedge id_card \rightarrow \text{entitled_discount} \wedge \\ oap \rightarrow id_card \wedge oap));$$

$$C_b(n+8, (\mathbf{why}(oap \rightarrow \text{entitled_discount}) \wedge id_card \rightarrow \text{entitled_discount} \wedge \\ \mathbf{why}(id_card) \wedge oap \rightarrow id_card \wedge oap)).$$

Party_B questions *id_card*, which he is free to do because *id_card* is not in C_b . Party_A denies it, as a result of an inconsistency in its working area, with the resulting commitments derived by Commitment rule Denial:

Commitment rule Denial:

After <stage,speaker,**denies**(Statement)>

$$C_s(\text{stage}+1, \text{Statements}^*) = C_s(\text{stage}, \text{Statements}^*) \cup \{\neg \text{Statement}\}$$

$$C_h(\text{stage}+1, \text{Statements}^*) = C_h(\text{stage}, \text{Statements}^*) \cup \{\neg \text{Statement}\}$$

If a denial of a statement has been made then the speaker and the hearer are obliged to place the negation of the statement in their commitment store.

Mackenzie (1985) does not provide a commitment rule for denial, because he does not grant denial the status of a locution modifier as we said before.

The resulting commitment stores after these pair of dialogue events are:

$$C_a(n+10, (oap \rightarrow \text{entitled_discount} \wedge id_card \rightarrow \text{entitled_discount} \wedge \\ oap \rightarrow id_card \wedge oap \wedge \neg id_card));$$

$$C_b(n+10, (\mathbf{why}(oap \rightarrow \text{entitled_discount}) \wedge id_card \rightarrow \text{entitled_discount} \wedge \\ \mathbf{why}(id_card) \wedge oap \rightarrow id_card \wedge oap \wedge \neg id_card)).$$

Party_B immediately demands that Party_A, having denied an immediate consequence of its commitments **resolve**{*oap*,*oap*→*id_card*/¬*id_card*}, which is now inconsistent (using modus ponens we have {*oap*,*oap*→*id_card*}/*id_card* which is inconsistent with ¬*id_card*):

Commitment rule Resolution Demand:

After <stage,speaker,**resolve**(Set_of_Statements/Statement)>

$$C_s(\text{stage}+1, \text{Statements}^*) = C_s(\text{stage}, \text{Statements}^*)$$

$$C_h(\text{stage}+1, \text{Statements}^*) = C_h(\text{stage}, \text{Statements}^*)$$

Resolution demands do not affect the commitment stores.

Party_A withdraws its previous denial restoring consistency by adjusting the commitments according to Commitment rule Withdrawal given in our overview of the dialogue scheme.

Party_B follows suit by also withdrawing the inconsistency, which if not removed would now leave it liable to a resolution demand from Party_A, and so the dialogue concludes with a shared description and discovery of the *misunderstanding* hidden in WA_a .

The resulting commitment stores after these three final dialogue events are:

$$C_a(n+13, (\text{oap} \rightarrow \text{entitled_discount} \wedge \text{id_card} \rightarrow \text{entitled_discount} \wedge \text{oap} \rightarrow \text{id_card} \wedge \text{oap}));$$

$$C_b(n+13, (\mathbf{why} (\text{oap} \rightarrow \text{entitled_discount}) \wedge \text{id_card} \rightarrow \text{entitled_discount} \wedge \mathbf{why}(\text{id_card}) \wedge \text{oap} \rightarrow \text{id_card} \wedge \text{oap})).$$

This example shows how this dialogue formalism provides us with the means for representing the elucidating-retracting mechanism, which is a helpful way for sorting out inconsistencies - conflict resolution - that are bound to happen in a cooperative working environment.

3.4. Summary

A dialogue formalism based on commitment and legality has been developed by Hamblin and extended by Mackenzie. It provides a framework within which logic can be seen as a discipline concerned with arguments and not only with proofs and derivations. To supply representation schemes to deal with the problem of negotiation, we have modified this framework and applied it to dialectical reasoning in computing.

In this chapter we have introduced part of this dialogue formalism through examples originating from software specification that could be addressed as negotiation problems. The dialogic approach used in the examples contrasts with those taken by existing specification schemes, methods and tools which are generally based on specification from a single party's point of view.

Mackenzie (1985) defines a series of *preferred valid consequences* like *modus ponens consequence*, *immediate inconsistency*, *immediate consequence* and *immediate consequence conditional*. He also defines some syntactically specifiable relations like *acceptability*, the quality of *being an answer to* and the relation of *weakness* between locutions. He needed all this machinery because he was concerned with logics.

Our aim is to tackle the problem of negotiation using computational models. For this reason our framework only captures part of the consequence relations above, especially *modus ponens* which is important for locution modifier Justification (and Resolution Demand). We will try to capture other relevant relations using reasoning strategies in future work. The scope of this work is limited to the introduction of some of the representation schemes that our framework can provide. For this purpose, the absorption of the commitment and dialogue rules in the framework seems to be enough.

PART II

A Framework for Dialogue Reasoning Systems

Chapter 4

Deontic Commitment

In Part I of this dissertation we have been using commitment without plunging deep into its nature. Hamblin's and Mackenzie's formalisms did not provide us with a structured way to deal with the commitments inside the commitment stores. This chapter starts the discussion on the topic of commitment. The notion of commitment first appears in deontic logics. The relations between deontic and commitment logics are investigated. A preliminary account of commitment logic (CL) is given. This logic fails to capture some important aspects attributed to commitments. Some brief examples are developed and a review of commitment is suggested.

4.1. The Formal Analysis of Commitment

The few attempts to define a commitment logic have always characterised it as an offshoot of deontic logic. In these schemes the notions of permission, obligation and commitment are normally prefixed by some sort of adjective, for example: moral, absolute, conditional and derived. It is necessary to understand the way these concepts are knitted together before we can achieve our objective of an *independent* commitment logic.

A good starting point is Aqvist (1984) who suggests that deontic logic 'is the logical study of the normative use of language and that its subject matter is a variety of normative concepts, notably those of obligation

(prescription), prohibition (forbiddance), permission and commitment. The first one among these concepts is often expressed by such words as 'shall', 'ought' and 'must', the second by 'shall not', 'ought not' and 'must not', and the third one by 'may'; the fourth notion amounts to an idea of conditional obligation, expressible by 'if ..., then it shall (ought, must) be the case that ____'.

Von Wright (1951), in his paper *Deontic Logic*, defined a system for such a logic, where 'O' and 'P' are deontic predicates applied to actions. There he uses the construct $O(A \rightarrow B)$ which could be read as *doing A commits us to do B* to express the notion of commitment.

Hintikka (1971) examines two possible candidates for expressing the notion of commitment. The first one is $[O(A \rightarrow B)]$, prima facie commitment, and the second is $[A \rightarrow OB]$ absolute commitment. He analyses some paradoxes of deontic logic showing their relation to the essential *problems* of material implication, and scrutinizes the differences between prima facie and absolute (duties) obligations.

Rescher (1958) in his paper *An Axiom System for Deontic Logic*, defines a system of commitment logic based on permission and obligation. There for the first time a specific deontic modality 'C' for expressing commitment is used.

"Here the symbol P is prefixed to an ordered pair of objects, the first of which is the name of a type of act (e.g., "to steal"), and the second of which is a description of a circumstance, possibly including actions that are taking or have taken place. By means of the machinery thus far developed it is possible to clarify the concept of (moral) commitment or derived obligation. The expression $\{q \ C \ p/c\}$, intended to be interpreted "q commits us to p in circumstances c" may be defined:

D4. $\{q \ C \ p/c\} = DF \ O(p/ c \& q)$.

We immediately have the theorems:

- T6.1. $\vdash [O(p/c) \ \& \ \{p \ C \ q/c\}] \rightarrow O(q/c)$
 T6.2. $\vdash [P(p/c) \ \& \ \{p \ C \ q/c\}] \rightarrow P(q/c)$
 T6.3. $\vdash [\{p \ C \ q/c\} \ \& \ \{q \ C \ r/ \ c\&p\}] \rightarrow \{p \ C \ r/c\}$
 T6.4. $\vdash \{p \ C \ q/c\} \rightarrow O(p \supset q/c)$
 T6.5. $\vdash [O(p \ \& \ q/c) \rightarrow \{p \ C \ q/c\}]$
 T6.6. $\vdash O^*(p) \rightarrow \{q \ C \ p/c\}$
 T6.7. $\vdash \{\sim p \ C \ p/c\} \rightarrow O(p/c)$ "

The use of circumstance as a subsidy for conditional permission (obligation), blurs the picture as Castaneda (1959) points out:

"It seems to me that Rescher failed to see the complete duality between obligation and permission, because of his sign '/' connecting the act and the circumstances. He conceives of it as some kind of conditional; but since it is not related to negation or conjunction or disjunction in any manner, some distortions are bound to appear."

Anderson (1959) in *Logic of Commitment* rewrites Rescher's system. There he uses the same types but avoids the discomfort associated with circumstance. 'O' stands for absolute obligation and 'P' for absolute permission. (' $\rightarrow$ ' is strict implication.)

"As (vague) adequacy criteria for the theory of commitment, the following may be suggested (reading " $p \ C \ q$ " as " p commits us to q " or " q is obligatory given p " or the like, and reading " Op " as "it is obligatory that p "). There should be as theorems at least:

- (11) $[p \ \& \ (p \ C \ q)] \rightarrow Oq,$
 (12) $[Op \ \& \ (p \ C \ q)] \rightarrow Oq,$
 (13) $[Pp \ \& \ (p \ C \ q)] \rightarrow Pq,$
 (14) $[(p \ C \ q) \ \& \ (q \ C \ r)] \rightarrow p \ C \ r,$
 (15) $(p \ C \ q) \rightarrow O(p \supset q),$ and
 (16) $(\neg p \ C \ p) \rightarrow Op."$

4.2. Moving from Deontic Logic to Commitment Logic

Now we examine and rewrite Anderson's system, removing from it the notions of permission and obligation. Our objective is to retain only the *essence* of commitment and characterise it independently of any notion of obligation or permission.

Anderson's theorem (11) $[[p \ \& \ (p \ C \ q)] \rightarrow Oq]$, says that if 'p' happens to be true and 'p' commits us to 'q' then we are obliged to 'q'.

Below we present an example showing some undesirable effects of this theorem:

Molumbra, a country somewhere in South America, has an old custom that the children of a murdered parent must take revenge by killing the murderer. Sue killed Fred and Gary's father. According to (11) - reading $[p \ C_F \ q]$ as *p commits Fred to q* where:

S: Sue has murdered Fred and Gary's father; (a circumstance)
K: to kill Sue. (an action)

- i) $S \ \& \ (S \ C_F \ K) \rightarrow O_F \ K;$
- ii) $S \ \& \ (S \ C_G \ K) \rightarrow O_G \ K.$

Let us now consider two alternative cases:

a) Impossible realisation:

Fred is a man and Gary is a baby. Is Gary still obliged to kill Sue?;

b) Accidental realisation:

Fred revenged himself by killing Sue. Is Gary still obliged to kill Sue?

In case (a) Gary is (temporarily) unable to perform his duty, while in case (b) Gary will never be able to revenge himself. These cases

exemplify situations where one is unable to honour an obligation due to some temporal or defeasible conditions.

From this example it can be seen readily that the relation between commitment and obligation in Anderson's system is not the one we are looking for. His system - following the deontic tradition - sees commitment as a side effect of permission and obligation. Treating 'C' in $[p \ C \ q]$ as a dyadic modality is also unsuitable for our purposes. Although the system uses absolute notions of permission and obligation, there is some sort of conditionality embedded in the dyadic operator which we would like to avoid. What we propose here is to use 'C' as a monadic modality. In this approach, $[p \ C \ q]$ is rewritten as $[C(p \rightarrow q)]$.

Now let us return to the previous example substituting $[Cp \wedge C(p \rightarrow q) \rightarrow Cq]$ for theorem (11). Some rephrasing is necessary because we are no longer considering actions but the states of affairs described by the commitments in the commitment stores.

S' : Sue is guilty of the murder of Fred and Gary's father;
K' : Sue's death.

- i') $C_F S' \wedge C_F (S' \rightarrow K') \rightarrow C_F K'$;
- ii') $C_G S' \wedge C_G (S' \rightarrow K') \rightarrow C_G K'$.

Formulas (i') and (ii') above, just state that Fred and Gary have a commitment to bringing about Sue's death. There is no obligation for revenge. What they have now is the commitment and not the obligation that could be derived from it.

A second example illustrates the use of commitment as derived obligation:

Molumbra's politicians have the habit of promising to build bridges if they are elected. Mr Frame, a renowned local politician promised to build a new bridge if he was elected. After being elected he refused to build the bridge. Let us examine Mr Frame's behaviour, first using

Anderson's theorem (11) and then using our concept of commitment, where:

F: Mr Frame won the election;

F': Mr Frame becomes the elected MP;

B: Mr Frame will build the bridge and

B': Mr Frame is responsible for building the bridge.

iii) $F \ \& \ (F \ C_F B) \rightarrow O_F B$;

iv) $C_F F' \wedge C_F (F' \rightarrow B') \rightarrow C_F B'$.

In formula (iii) at the most Mr Frame can be considered a liar. It is not even clear if he still has a commitment to the building of the bridge after failing to satisfy his obligation to do it. In formula (iv) it is clear that his commitment to building the bridge holds, even if he actually fails to do it. He is definitely open to a demand from his electorate for a bridge. This is the notion we wish to capture. Therefore, if one has a commitment to a certain state of affairs, one is answerable for the achievement of this state of affairs. Our notion of commitment says nothing about the party's ability to bring it about.

Now we rewrite the remaining theorems:

Theorems (12) and (13) lead us to the same sort of understanding of commitment as that given by theorem (11).

Theorem (14) characterises something about the transitivity of commitments. Using 'C' as a monadic modality we have: $[C(p \rightarrow q) \wedge C(q \rightarrow r) \rightarrow C(p \rightarrow r)]$.

Theorem (15) establishes the link between commitment and obligation that we are trying to avoid in CL.

The rewriting of theorem (16) as $[C(\neg p \rightarrow p) \rightarrow Cp]$ is undesirable in CL. But to avoid it CL has to be a logic where $\phi \leftrightarrow \psi$ does not imply $C\phi \leftrightarrow C\psi$. This is because $(\neg p \rightarrow p) \rightarrow p$. If we keep away from the sort of problems that non-normal modal logics (Chellas 1980) have - as implication and

modus ponens play an important part in our notion of commitment - we cannot get rid of theorem (16) as shown below:

$\frac{p \rightarrow p}{}$	Axiom
$\frac{(\neg p \rightarrow p) \rightarrow p}{}$	Necessitation
$\frac{C((\neg p \rightarrow p) \rightarrow p)}{}$	Distribution
$C(\neg p \rightarrow p) \rightarrow Cp$	

4.3. An Outline of a Commitment Logic (CL)

We now give the formal framework for a Commitment Logic. A semantics is outlined and proof rules are given.

While being obliged generally forces a person to perform an action, having a commitment establishes a family of ways for a person to behave, in a manner consistent with the information available to the person. Our semantics is based on these two themes: partiality and delayed realisation of commitments. We will try to achieve this using information states - partial valuations on the language - as used in Veltman (1984).

Traditionally deontic logics contain an unary operator 'O' which acts on formulas. The idea is that an obligation to a formula is an obligation to perform actions which will bring about the truth of that formula. These actions must be the very next ones performed. More recently, deontic logics have been studied in which 'O' applies directly to actions (Koshla & Maibaum 1987).

Our notion of commitment is weaker than obligation. It intentionally does not say anything about when or how the commitment is to be realised. A commitment guides a person's behaviour, for she will wish to realise it, but it does not dictate her behaviour. Typically there are many ways of realising one's commitments, or they may even become realised accidentally by another person's actions.

4.3.1. Semantics

Definition: Language L

Let L be the propositional language defined as follows:

$p, q, r, \dots \in L$ (atomic propositions)

If $\phi, \psi \in L$ then $\neg\phi, \phi \wedge \psi, \phi \vee \psi, \phi \rightarrow \psi, C\phi \in L$.

L is the language of ordinary propositional logic with a modal operator 'C'. Our interpretation structures are models $M = \langle I, R, V \rangle$ where I is a set of information states, R is a relation between them and V is a family of partial valuations on the atomic propositions. The frame $\langle I, R \rangle$ has no strict endpoints: $\forall x \in I. \exists y \in I. xRy$. V maps information state x to a function V_x , from atomic propositions to truth values {t, u, f} in such a way that truth values are persistent through R: if xRy then for any p, either $V_x(p) = u$ or $V_y(p) = V_x(p)$.

The truth and falsity of formulas at information states is defined in the following way. For each formula ϕ we give truth conditions ($x \Vdash \phi$) and falsity conditions ($x \Vdash \neg\phi$). ϕ is undefined at x if it does not meet either of these conditions:

$x \Vdash p$	iff	$V_x(p) = t$
$x \Vdash \neg p$	iff	$V_x(p) = f$
$x \Vdash \phi \wedge \psi$	iff	$x \Vdash \phi$ and $x \Vdash \psi$
$x \Vdash \neg(\phi \wedge \psi)$	iff	$x \Vdash \neg\phi$ or $x \Vdash \neg\psi$
$x \Vdash \phi \vee \psi$	iff	$x \Vdash \phi$ or $x \Vdash \psi$
$x \Vdash \neg(\phi \vee \psi)$	iff	$x \Vdash \neg\phi$ and $x \Vdash \neg\psi$
$x \Vdash \phi \rightarrow \psi$	iff	$x \Vdash \phi$ implies $x \Vdash \psi$
$x \Vdash \neg(\phi \rightarrow \psi)$	iff	$x \Vdash \phi$ and not $x \Vdash \psi$
$x \Vdash \neg\neg\phi$	iff	$x \Vdash \phi$
$x \Vdash C\phi$	iff	$\exists n > 0. \forall m \geq n. \forall y \in I. \text{ if } xR^m y \text{ then } y \Vdash \phi$
$x \Vdash \neg C\phi$	iff	$\exists n > 0. \exists y \in I. xR^n y$ and $\forall m \geq 0. \forall z \in I. \text{ if } yR^m z \text{ then } z \Vdash \neg\phi$

Thus the propositional connectives are evaluated locally according to Kleene's strong three-valued truth-tables (Urquhart 1986). The intuition behind how 'C' is evaluated is as follows. Whereas in deontic logics $O\phi$ means that ϕ has to occur in every next state, here $C\phi$ means that ϕ has to occur within a uniformly finite number of steps (as we discussed in the beginning of section 4.3.).

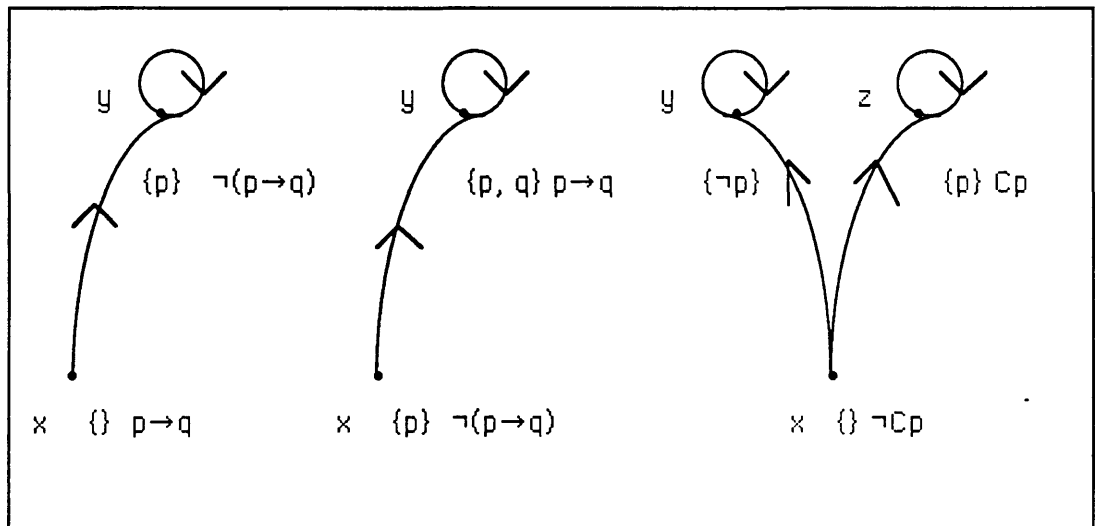
Definition Persistence

ϕ is persistent if for all models $\langle I, R, V \rangle$ and $x, y \in I$,
if $x \Vdash \phi$ and xRy then $y \Vdash \phi$.

Proposition: Persistence of $\wedge, \vee, 'C'$.

If ϕ, ψ are persistent,
then so are $\phi \wedge \psi, \phi \vee \psi, \neg(\phi \wedge \psi)$ and $\neg(\phi \vee \psi)$.
For all $\phi, C\phi$ is persistent.

Persistence does not extend to $\phi \rightarrow \psi, \neg(\phi \rightarrow \psi)$ and $\neg C\phi$ as the following examples show. (In the following information state diagrams, sets of literals adjacent to the states contain the literals that hold there. If neither p nor its negation are in the set, it is undefined there.)



Proposition: Consistency

For all models $\langle I, R, V \rangle$, all $\phi \in L$ and all $x \in I$, not $x \Vdash \neg\phi \wedge \phi$.

Definition: Consequence

Let Γ be a set of formulas in L and ϕ a formula.

$\Gamma \models \phi$ iff for any model $\langle I, R, V \rangle$ and state $x \in I$,
if $x \Vdash \psi$ for each $\psi \in \Gamma$ then $x \Vdash \phi$.

Below we examine a selected set of formulas that characterise CL.

The following formulas are valid:

$$1) C(\phi \wedge \psi) \rightarrow C\phi \wedge C\psi$$

If Joan is committed to becoming *a married person* and *a parent*, then Joan is committed to becoming *a married person* and committed to becoming *a parent*.

$$2) C\phi \vee C\psi \rightarrow C(\phi \vee \psi)$$

If Joan is committed to becoming *a sculptress* or committed to becoming *a painter* then Joan is committed to becoming *a sculptress* or *a painter*.

$$3) C\phi \wedge C(\phi \rightarrow \psi) \rightarrow C\psi$$

If Joan has a commitment to becoming *a married person*, and Joan has a commitment to the idea that being *a married person* implies being *a mother*, then Joan has a commitment to becoming *a mother*.

$$4) C\neg\varphi \rightarrow \neg C\varphi$$

If Joan has a commitment to not becoming *a married person* then Joan cannot have a commitment to becoming *a married person*.

The following formulas are not valid:

$$1) \neg C\varphi \rightarrow C\neg\varphi$$

Joan does not have a commitment to becoming *a married person*, but she need not have a commitment to not becoming *a married person*.

$$2) C\varphi \rightarrow \varphi$$

Joan's marital commitment may yet be unrealised.

$$3) C\varphi \vee \neg C\varphi$$

Joan is undecided about her commitment to becoming *a married person*.

4.3.2. Proof Rules

We now give all-introduction Gentzen style proof rules for the connectives. We decided to design the commitment logic using this kind of presentation because we wanted to implement the logic using the 'ωp Generic Logic Environment' (Dawson and Sadler 1988, Dawson 1989). 'ωp' as it stood then used this style of rules. We were unable to accomplish a satisfactory implementation mainly because the simultaneous development of both, 'ωp' and CL made the task a very difficult one. Anyway we stuck to this presentation for CL, moving to a natural deduction presentation as for the rules that describe the calculus proposed in the following chapters. Let '⊢' be the minimal proof relation between sets of formulas and formulas defined by the following rules:

Necessitation

$$\frac{\Gamma \vdash \phi}{C\Gamma \vdash C\phi}$$

A commitment to the premise of an argument forces a commitment to its conclusion. The rule shows that commitments are closed under consequence.

Coherence

$$\frac{\Gamma \vdash C\phi \vee \psi}{\Gamma, C\neg\phi \vdash \psi}$$

This rule proves that one cannot concurrently have a commitment to something, and to the negation of that thing.

Thinning

$$\frac{\Gamma \vdash \phi}{\Gamma, \Delta \vdash \phi}$$

Below we present the three-valued propositional rules for ' $\rightarrow$ ' and ' $\vee$ '.
The connective ' $\wedge$ ' may be defined by the following deMorgan rules:

$$\begin{aligned}\phi \wedge \psi &\leftrightarrow \neg(\neg\phi \vee \neg\psi) \\ \neg(\phi \wedge \psi) &\leftrightarrow \neg\phi \vee \neg\psi\end{aligned}$$

$$\frac{\Gamma, \phi \vdash \psi}{\Gamma \vdash \phi \rightarrow \psi} \rightarrow R$$

$$\frac{\Gamma \vdash \phi \quad \Gamma, \psi \vdash \beta}{\Gamma, \phi \rightarrow \psi \vdash \beta} \rightarrow L$$

$$\frac{\Gamma \vdash \phi \quad \Gamma \vdash \neg\psi}{\Gamma \vdash \neg(\phi \rightarrow \psi)} \neg \rightarrow R$$

$$\frac{\Gamma, \phi, \neg\psi \vdash \beta}{\Gamma, \neg(\phi \rightarrow \psi) \vdash \beta} \neg \rightarrow L$$

$$\frac{\Gamma \vdash \phi \quad \Gamma \vdash \psi}{\Gamma \vdash \phi \vee \psi} \vee R$$

$$\frac{\Gamma, \phi \vdash \beta \quad \Gamma, \psi \vdash \beta}{\Gamma, \phi \vee \psi \vdash \beta} \vee L$$

$$\frac{\Gamma, \neg\phi, \neg\psi \vdash \beta}{\Gamma, \neg(\phi \vee \psi) \vdash \beta} \neg \vee L$$

$$\frac{\Gamma \vdash \neg\phi \quad \Gamma \vdash \neg\psi}{\Gamma \vdash \neg(\phi \vee \psi)} \neg \vee R$$

Proposition: Soundness

If $\Gamma \vdash \varphi$ then $\Gamma \models \varphi$.

The proof for the ordinary connectives is standard.

Proof for *Necessitation* rule:

We show that if $\Gamma \models \varphi$ then $C\Gamma \models C\varphi$. (Γ is assumed to be finite)

Let $\Gamma = (\beta_1, \dots, \beta_k)$

Suppose $\Gamma \models \varphi$, and $x \Vdash C\Gamma$ (i.e. $x \Vdash C\beta_j$ for each $\beta_j \in \Gamma$), where $x \in I$ is in a model $\langle I, R, V \rangle$.

Since $x \Vdash C\beta_j$, let n_j be the n given in the definition of $\Vdash$.

Let $n = \max \{n_1, \dots, n_k\}$.

For any $y \in I$ such that $xR^n y$, $y \Vdash C\beta_j$ for each j and so $y \models \varphi$.

Thus $x \models C\varphi$.

However x was arbitrary so $C\Gamma \models C\varphi$.

The proof for *Coherence* is similar.

4.4. Summary

Much effort towards a formal understanding of commitment has been devoted to deontic logics, logics of permission and obligation. However, there are important differences between these two notions. While obligations apparently ask for immediate responses (actions), there is a sense of delayed effect embedded in commitments (behaviour). For example, you are obliged to pay taxes, and you have a commitment to being a good citizen. In other words, one does not have a commitment to perform actions, but to the achievement of states of affairs. If one has a commitment to a certain state of affairs, then either one observes the occurrence of that state of affairs or retains one's commitment to it. Eventually that commitment will have to be satisfied. Commitments are of a passive nature while obligations are of an active kind. People should behave coherently with their commitments and with the

information available to them.

The *essence* of commitment for us, is that if one has a commitment to a certain state of affairs, one is answerable for the achievement of this state of affairs. Unfortunately our notion of commitment says nothing about the party's ability to bring it about. For example, Mr Frame has committed himself to build a bridge that for technical reasons - soil, budget or available technology - is not possible to be built. His electorate will demand it from him anyway.

However, CL's proof rules fail to capture the delayed realisation of commitment paramount in the semantics (given the evaluation rules for $x \models C\phi$ and $x \models \neg C\phi$ in section 4.3.1.). In the following chapters we review the notion of commitment and try to provide a calculus for dealing with it. This time we will approach the notion of commitment having in mind that if one is committed to something, one is aware of this thing - if one has a commitment to do something then one is aware of the object of one's commitment. At least three important aspects of commitment will be imported from CL into the new calculus: its three-valuedness (having, not having and lacking commitments), allowing commitments to be weakened ($C\neg\phi \rightarrow \neg C\phi$), and not allowing commitments to be strengthened ($\neg C\phi \rightarrow C\neg\phi$).

Finally, regarding Arthur N. Prior's paradoxes of derived obligations ('commitment') as they are presented in Aqvist (1984), we have no common ground for analysing them in respect to CL, because in CL all links between obligation and commitment were severed.

Chapter 5

Revisiting Commitment

By looking at the way that deontic logic dealt with the notion of commitment, we tried to develop a commitment logic in the previous chapter. This logic failed to capture the *delayed realisation* aspect that we attributed to commitments. Chapter 5 reviews commitment approaching it this time from the *awareness* point of view. Some important aspects observed using the deontic approach are preserved - namely the three-valuedness of commitments, the permission to weaken commitments and the prohibition to strengthen them.

We briefly review the notion of commitment used in speech act theory. At the end of this chapter we propose a Framework for Dialogue Reasoning Systems comprising a Commitment Calculus (CC) and a Commitment Action Dialogue Reasoning System (CADReS).

5.1. A Notion of Commitment

Having a commitment to bring about a state of affairs (s-o-a), presses one to behave in a manner consistent with the achievement of that s-o-a. It is important to see that one is neither alone nor aware of everything that is taking place on the planet. Thus, we could go further saying that having a commitment establishes a family of ways for a party to behave, in a manner consistent with the information available and with the role that that party performs in its community.

There is a relationship between being in the situation of having a commitment and the behaviour pattern that follows from it. In that sense, commitment reminds us of belief. One behaves according to one's beliefs. But belief, especially in the sense of faith, is not an operational notion. One can hide one's beliefs or truly need not be capable of expressing them. Commitments should not only be expressible but also available for public examination. It is easier to check one's commitments against one's behaviour this way. Moreover, a wider spectrum of agents are capable of undertaking commitments, human beings, corporations and governments while beliefs are better used when applied to people.

From the above, it is implicit that there is no commitment without being conscious of the objects of one's commitment. It also implies that there is a difference between not having a commitment and its absence. While the former involves cognizance and rejection of some data, not much can be said about the latter. This three-valued aspect of commitment influences the way that we design the commitment stores in the next chapter.

Another important characteristic of commitments - imported from the work developed on deontic commitment - that we wish to capture in the calculus, is that while it is fair to weaken commitments ($C\neg\phi \rightarrow \neg C\phi$) it is forbidden to strengthen them ($\neg C\phi \rightarrow C\neg\phi$).

Given that one is committed to achieve some desired s-o-a, one adjusts one's behaviour pattern to suit one's commitment. In other words, one's commitments impose constraints on one's behaviour. One way of describing one's behaviour is by looking at one's structure of permissions and obligations - do's and don't's. A commitment is an engagement or involvement that restricts freedom of action. If one is committed to something, one should stick to it.

One is tempted to join the idea of having a commitment with that of having a goal, because in either case, success will be equated with the realisation of that envisaged s-o-a (goal or commitment). But from a computing perspective, goal is the query that one makes for a database;

or relaxing it a bit, it is just the final state that is to be achieved. Moreover, associating commitment with goal, we lose the awareness aspect of the former (it is not clear if after achieving a goal whether one should keep conscious of the object of one's goal). Having said that, we feel free to connect commitment with goal, whenever it sheds some light on our understanding.

Finally, advancing the use of commitment, we are not neglecting other concepts like intention, belief and knowledge. They all play an important part in the process of reasoning. But at the current stage of this work, we see commitment as a pragmatic *amalgam* for the interaction aspects of all of them. We hope in future work we will be able to interconnect all these concepts by means of specific axioms and/or rules.

5.2. The Etymology of Commitment

Commitment's etymology proceeds from the latin:

[COM_MITTO] to connect, of two or more objects, to bring, to join, to combine into one whole, to put together;

[CON- CUM FIN] connection of one object with another;

[MITTO] to set in motion, to cause to go, let go, to send, to despatch; to send word to announce, to tell, to report anything to anyone.

A first assessment of the word's etymology stresses the idea of connection, binding between different objects. A closer inspection of the two words that comprise its root furthers our insight into its meaning. It indicates that this connection sets something in motion, triggers some kind of process or event and confers a mental, and even public, status to this connection. The english word *mission*, also derived from [MITTO], enhances even more our understanding of the word.

Therefore, by uttering *I am committed to a Nuclear-Free World*; I am

undertaking a mission to bring about a Nuclear-Free World. Normally, the fulfilment of a mission implies the promotion of the s-o-a that describes the mission's goal. Sometimes, as in the case above, there is no distinction between the mission and the promotion of the desired s-o-a.

Commitment is the state of being committed. There is no difference between saying *I am committed to a Nuclear-Free World* or *I have a commitment to a Nuclear-Free World*. In both cases, after stating it I find myself bound to the achievement of that s-o-a.

What are the consequences of having a commitment?

The first is awareness of the desired s-o-a. When I say *I am committed to a Nuclear-Free World*, the s-o-a named as *Nuclear-Free World*, must be known to me at the time I am asserting my commitment to it. Therefore there is no commitment without consciousness. Next comes the formulation and activation of a plan to bring about the desired s-o-a. Commitment is normally related to volition - the exercise of the will. To commit, as in perpetrate or achieve, is a voluntary action. Commitment as resolution, perseverance or dedication deals with individual volition; while as a promise, it deals with conditional social volition. Commission and committee suggest general social volition, authority, abstract relations and order. Finally, commitment as debt or duty brings up the notions of possessive relations, obligations and morality.

5.3. State of Affairs

About general s-o-a Pollock (1984). says: "In many ways, states of affairs resemble propositions. In particular, they are truth bearers of a sort. States of affairs are not literally true or false, but obtaining and not obtaining are truth-like properties". He makes a distinction between transient s-o-a (*being a patriot*) and nontransient s-o-a (*being a patriot during WWII*).

One can become committed to either sort of s-o-a (transient or nontransient). The latter fits better within our notion of commitment

where one retains one's commitment even after realising it. Is one going to keep one's commitments forever? No, provided that there is a mechanism allowing for their retraction. The framework that we develop in the following chapters will cater for this.

One can become committed to actions, for actions promote the achievement of s-o-a's - from now on we use either form. Having a commitment to paying my debts, boils down to having a commitment to transferring money from my account to my lender's account. The obtaining of this s-o-a could be asserted after checking that my lender's account was increased by the same amount of money that was subtracted from mine, securing that it corresponds to the debt's amount. Commitment to conditionals is acceptable for a conditional is a constraint on a s-o-a.

5.4. Conversation, Commitment and Speech Acts

It is not only through utterances of the form *I am committed to* or *I have a commitment to* that one finds oneself having commitments. For example, when your auntie rings you saying that she is coming for dinner on Saturday evening, you had better say a clear no otherwise you are committing yourself to that fact. Moreover, our parties are far from being omnipotent. They are fallible and unable to deal with all the matters that comprise their everyday life. But still they accept and reject statements about the world all the time. Accepting and rejecting amount to engaging and disengaging. Listening to the weatherman saying that it is going to snow today, gives you precious data for deciding which means of transportation to use. Also when you read the memo that says that the corporation - your employer - is expanding its activities, even if that expansion has nothing to do with the role that you perform in the company, you are still engaged in the expansion although you are not going to play an active part in it.

The notion of commitment also plays an important part in speech act theory:

There are five (and only five) fundamental illocutionary points (things one can do with an utterance):

Assertive: Commit the speaker (in varying degrees) to something being the case - to the truth of the expressed proposition (as representing an actual s-o-a in the world of utterance);

Commissive: Commit the speaker (in varying degrees) to some future course of action;

Directive: Attempt (in varying degrees) to get other people (hearer) to do things. These include both questions (which can direct the hearer to make an assertive speech act in response) and commands (which direct the hearer to carry out some linguistic or non-linguistic act);

Declaration: Bring about the correspondence between the propositional content of the speech act and reality (e.g. pronouncing a couple married);

Expressive: Express a psychological state about a state of affairs (e.g., apologizing and praising). (Winograd 1988 pp 627-628 on Searle and Vanderveken 1987 pp 37-38)

Assertives and Comissives are strongly linked with the notion of commitment:

a) Assertive: If a language user states his attitude in respect of the acceptability of (the propositional content of) a particular statement or combination of statements, he thereby indicates that he regards that statement or those statements as an expressed opinion. By advancing a positive or negative point of view he *has committed himself positively or negatively* to that expressed opinion. In principle this implies that he must be prepared to defend his point of view in respect of the expressed opinion against attack from those to whom he has communicated it.

This means that every statement capable of having the specific consequence that it gives rise to a dispute in which the person making

the statement has a conditional *obligation to defend* his statement, may be regarded as an *expressed opinion*. This obligation to defend (the result of a certain committedness) we consider to be a general feature of *assertives*, distinguishing them as a class from other illocutionary acts. According to this view, then, both the advancing of an expressed opinion and the propounding of a point of view may be regarded as the performance of an *assertive*. (van Eemeren & Grootendorst 1984; *italics* by the authors.)

b) Commissives: The utterance by which the listener (now acting as speaker) makes known his acceptance or rejection has the illocutionary force of a *commissive*, since the illocutionary purpose of *accept* and *reject* is of course to *commit* the speaker positively or negatively to the propositional content of his utterance, the direction of fit is *from-world-to-worlds* and the sincerity condition relates to the speaker's *intention* (cf Searle 1979: 14-15).

In the last lecture in *How to Do Things with Words*, Austin, who like us regards *accept* as an illocution, ranks acceptance with the *expositives*, but he also observes of this category that some of the illocutions included in it might equally justifiably have been placed in other categories. According to him, *accept* (and some other illocutions) might also have been considered for the category of *commissives*, which includes, for example, *promise* (1976:162). We find this latter classification more satisfactory because *accept* has in common with *promise* and other commissives that the illocutionary purpose is in specific manner *to commit the speaker to a particular proposition*. (van Eemeren & Grootendorst 1984; *italics* by the authors)

From the material shown above, we feel confident enough to say that our understanding of commitment does not contradict the one advanced by speech act theory. We are only dealing with a part of it where statements are left unanalysed. For the current stage of this work speech act theory is not particularly relevant but for future extensions it will have to be taken into account.

5.5. A Framework for Dialogue Reasoning Systems

Hamblin (1987) describes the state transformations occurring in the environment (from a party's point of view), being caused either by *deeds* - where party is the active agent - or *happenings* - where party is a passive observer of the changes that are taking place.

A re-interpretation of this model is presented in figure 5.1, where we substitute Dialogue Events for Deeds and divide the state of affairs into World - a global database - and Commitment Stores - a local database.

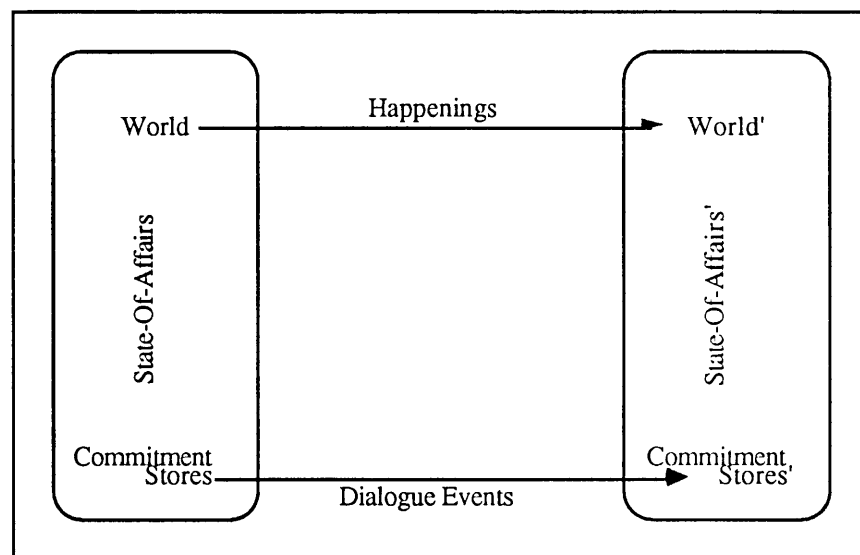


Fig 5.1 A model of the environment

The framework for dialogue reasoning systems that we propose below, is only concerned with the dialogic part of the model. It consists of a Commitment Calculus and a Commitment Action Dialogue Reasoning System. While the former defines the relationship between commitments inside individual commitment stores, the latter concerns itself with the proper ordering of locutions and their effects on the commitment stores.

The figure below illustrates the relationship between CC and CADReS. While CADReS is busy with the dialogue process, thus managing the insertion/deletion of commitments in the commitment stores, CC

reasons with the result of this process. CC never generates commitments, although it might seem to be doing this while inferring the consequences - implicit commitments - of the commitments - explicit commitments - already in the commitment stores.

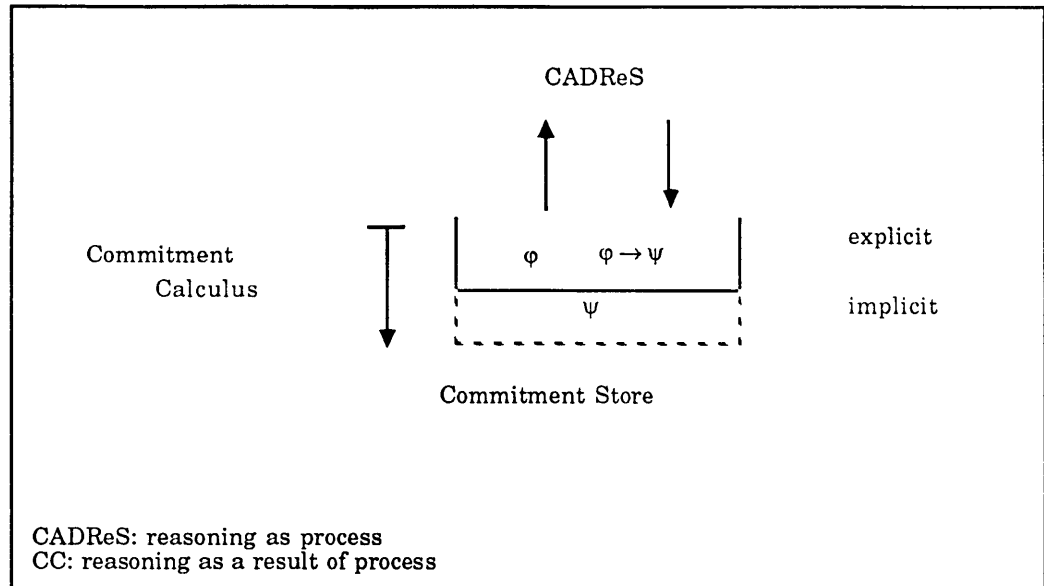


Fig 5.2 A Framework for Dialogue Reasoning Systems

In the following chapters we develop CC and CADReS, and in light of them we revisit the software specification examples of chapter 3.

Chapter 6

Commitment Calculus

A Commitment Calculus (CC) for dealing with the consequences of commitments inside the commitment stores is developed in this chapter. Commitment is used to represent the parties' range of information in the dialogue. Having a commitment establishes a family of ways for a party to behave in a manner consistent with the information available and with that party's role in its community.

Each party has a commitment store, where the unfolding of the dialogue is recorded from its point of view. Commitment stores are open to general observation, enabling the parties 'to anticipate the actions of the others and coordinate them with their own' (Winograd 1988).

But what are the consequences of having commitments? How can one determine if one's or the other's commitment store is inconsistent? Although becoming inconsistent does not mean the end of times, it may put one in a vulnerable position.

These and other questions were the motivation for designing such a calculus. We are not interested in giving a definitive meaning to the notion of commitment, but solely providing a framework within which to operate it. Our treatment of commitment and therefore its calculus is based on the discussion developed in the previous chapters.

For the sake of clarity, each party will not only have a commitment store for its positive and negative commitments - 'C' commitment store

(called $\mathbb{C}$) - but also a 'D' commitment store (called $\mathbb{D}$) as a place for the statements which the party is not committed to. We decided to design the stores in this way, because it is very revealing about the three-valued nature of our notion of commitment. The choice for the letter 'D' is because it is the next letter in our alphabet, and not to make the word *discommitment*, which fits better for the idea of lack of commitment.

6.1. Language

Definition: *Language L'*

Let L' be the propositional language:

$p, q, .. \in L'$ (atomic propositions)

If $\phi, \psi \in L'$ then $\neg\phi, \phi \wedge \psi, \phi \vee \psi, \phi \rightarrow \psi \in L'$.

Notation: Throughout the rest of this section we are going to use

ϕ, ψ to range over propositions in L' and

Γ, Δ to range over sets of propositions in L' .

Definition: *Language CL*

Let CL be the commitment propositional language:

If $\phi \in L'$ then $\phi, C\phi, D\psi \in CL$.

Definition: $C\Gamma = \{C\phi \mid \phi \in \Gamma\}$

Definition: $D\Gamma = \{D\phi \mid \phi \in \Gamma\}$

Definition: $\neg\Gamma = \{\neg\phi \mid \phi \in \Gamma\}$

Notation: Throughout the rest of this section we are going to use

ϕ, ψ to range over propositions in CL ($C\phi, ... D\psi$) and

Γ, Δ to range over sets of propositions in CL ($C\Gamma, ... D\Delta$).

6.2. Membership Semantics

In this section we develop a membership semantics for the commitment calculus. Gardenfors (1988) develops a membership semantics - one in which truth in an epistemic state is determined by membership of a set - for theory revision which is not relevant at the current stage of this work.

In our semantics states-of-affairs are described by propositions. The truth and falsity of formulas is defined by their membership status in the commitment stores. For each formula ϕ we check if it belongs to $\mathbb{C}$ or $\mathbb{D}$. ' ϕ ' is undefined if it does not belong to either commitment store.

$\mathbb{C}_{\wedge}$

$$(\phi \wedge \psi) \in \mathbb{C} \quad \text{iff} \quad \phi \in \mathbb{C} \text{ and } \psi \in \mathbb{C}$$

$\mathbb{C}_{\vee}$

if

$$\phi \in \mathbb{C} \quad \text{then} \quad (\phi \vee \psi) \in \mathbb{C}$$

$$\psi \in \mathbb{C} \quad \text{then} \quad (\phi \vee \psi) \in \mathbb{C}$$

if $(\phi \vee \psi) \in \mathbb{C}$ and

$$\neg\psi \in \mathbb{C} \quad \text{then} \quad \phi \in \mathbb{C}$$

$$\neg\phi \in \mathbb{C} \quad \text{then} \quad \psi \in \mathbb{C}$$

$$\psi \in \mathbb{D} \quad \text{then} \quad \neg\phi \in \mathbb{D}$$

$$\phi \in \mathbb{D} \quad \text{then} \quad \neg\psi \in \mathbb{D}$$

$\mathcal{C}_{\neg\wedge}$

if

$\neg\varphi \in \mathcal{C}$

then

$\neg(\varphi \wedge \psi) \in \mathcal{C}$

$\neg\psi \in \mathcal{C}$

then

$\neg(\varphi \wedge \psi) \in \mathcal{C}$

if $\neg(\varphi \wedge \psi) \in \mathcal{C}$ and

$\varphi \in \mathcal{C}$

then

$\neg\psi \in \mathcal{C}$

$\psi \in \mathcal{C}$

then

$\neg\varphi \in \mathcal{C}$

 $\mathcal{C}_{\neg\vee}$

$\neg(\varphi \vee \psi) \in \mathcal{C}$

iff

$\neg\varphi \in \mathcal{C} \text{ and } \neg\psi \in \mathcal{C}$

 $\mathcal{D}_{\wedge}$

if

$\varphi \in \mathcal{D}$

then

$(\varphi \wedge \psi) \in \mathcal{D}$

$\psi \in \mathcal{D}$

then

$(\varphi \wedge \psi) \in \mathcal{D}$

if $(\varphi \wedge \psi) \in \mathcal{D}$ and

$\varphi \in \mathcal{C}$

then

$\psi \in \mathcal{D}$

$\psi \in \mathcal{C}$

then

$\varphi \in \mathcal{D}$

$\neg\varphi \in \mathcal{D}$

then

$\psi \in \mathcal{D}$

$\neg\psi \in \mathcal{D}$

then

$\varphi \in \mathcal{D}$

 $\mathcal{D}_{\vee}$

$(\varphi \vee \psi) \in \mathcal{D}$

iff

$\varphi \in \mathcal{D} \text{ and } \psi \in \mathcal{D}$

$\mathcal{D}_{\neg\wedge}$

$\neg(\varphi \wedge \psi) \in \mathcal{D}$ iff $\neg\varphi \in \mathcal{D}$ and $\neg\psi \in \mathcal{D}$

 $\mathcal{D}_{\neg\vee}$

if

$\neg\varphi \in \mathcal{D}$ then $\neg(\varphi \vee \psi) \in \mathcal{D}$

$\neg\psi \in \mathcal{D}$ then $\neg(\varphi \vee \psi) \in \mathcal{D}$

if $\neg(\varphi \vee \psi) \in \mathcal{D}$ and

$\neg\varphi \in \mathcal{C}$ then $\neg\psi \in \mathcal{D}$

$\neg\psi \in \mathcal{C}$ then $\neg\varphi \in \mathcal{D}$

 $\mathcal{C}_{\rightarrow}$

if $(\varphi \rightarrow \psi) \in \mathcal{C}$ and

$\varphi \in \mathcal{C}$ then $\psi \in \mathcal{C}$

$\neg\psi \in \mathcal{C}$ then $\neg\varphi \in \mathcal{C}$

 $\mathcal{D}_{\rightarrow}$

if

$\varphi \in \mathcal{C}$ and $\psi \in \mathcal{D}$ then $(\varphi \rightarrow \psi) \in \mathcal{D}$

$\neg\varphi \in \mathcal{D}$ and $\neg\psi \in \mathcal{C}$ then $(\varphi \rightarrow \psi) \in \mathcal{D}$

 $\mathcal{D}_{\neg}$

if $\varphi \in \mathcal{C}$ then $\neg\varphi \in \mathcal{D}$

C $\neg$

if $\neg\varphi \in \mathbb{C}$ then $\varphi \in \mathbb{D}$

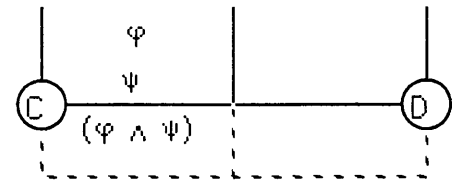
6.3. Rules

From this semantics we can read off a set of rules. These rules envisage consistency preservation inside the commitment stores. Each rule is explained by the drawing that follows it, which depicts the *membership* semantics shown above. For example, the $\mathbb{C}\wedge$ case in the semantics, corresponds to the $\mathbf{C}\wedge$ case in the rules. The premisses appear inside either thick outlined open boxes, according to their modalities - formulas preceded by C's go to C-stores and formulas preceded by D's go to D-stores. The conclusion appears in one of the dotted boxes.

Below we present the rules in a different order from that given in the semantics. Here we are concerned with showing when two sets of rules behave like duals. In the cases that duality is not attained, we point out the cause. Most of the rules are accompanied by additional text, to explain and guide the reader throughout this section. We also present some of the rules that we do not have in the calculus, giving the reasons for not having them.

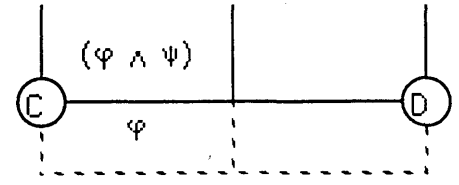
C $\wedge$

$$\frac{\mathbb{C}\varphi, \mathbb{C}\psi}{\mathbb{C}(\varphi \wedge \psi)}$$

C $\wedge$ I

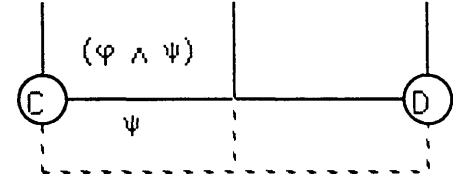
Rule C $\wedge$ I says that if one is committed to φ and committed to ψ , then one is committed to φ and ψ .

$$\frac{C(\varphi \wedge \psi)}{C\varphi}$$

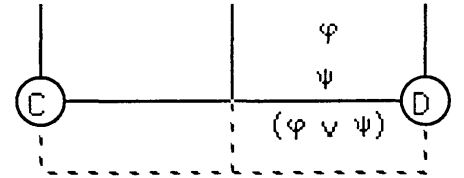
C $\wedge$ E1

If I'm committed to being *a good citizen* and *a parent*, then I'm committed to being *a good citizen*.

$$\frac{C(\varphi \wedge \psi)}{C\psi}$$

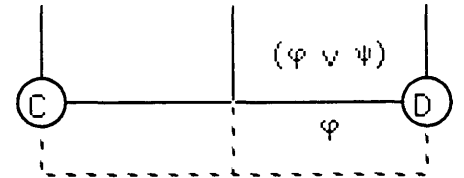
C $\wedge$ E2**D $\vee$**

$$\frac{D\varphi, D\psi}{D(\varphi \vee \psi)}$$

D $\vee$ I

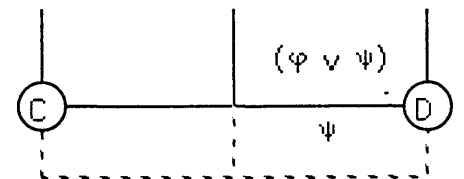
Rule D $\vee$ I says that if one is not committed to φ and not committed to ψ , then one is not committed to either φ or ψ .

$$\frac{D(\varphi \vee \psi)}{D\varphi}$$

D $\vee$ E1

If I'm not committed to being either *a good citizen* or *a parent*, then I'm not committed to being *a good citizen*.

$$\frac{D(\varphi \vee \psi)}{D\psi}$$

D $\vee$ E2

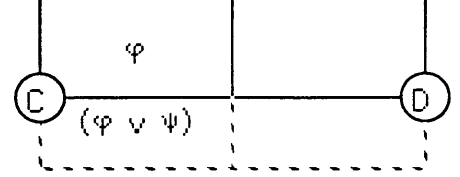
The two sets of rules **C $\wedge$** and **D $\vee$** above are duals. This implies that the rules for dealing with conjunctions of commitments are similar to the

rules for dealing with disjunctions of D-commitments.

C_∨

$$\frac{C\varphi}{C(\varphi \vee \psi)}$$

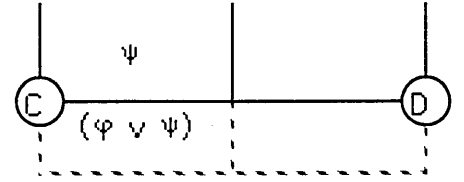
C_∨I1



Rule C_∨I1 says that if one is committed to φ , then one is committed to φ or ψ .

$$\frac{C\psi}{C(\varphi \vee \psi)}$$

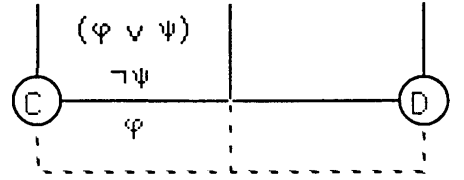
C_∨I2



If I'm committed to being *a parent*, then I'm committed to being *a good citizen or a parent*.

$$\frac{C(\varphi \vee \psi), C\neg\psi}{C\varphi}$$

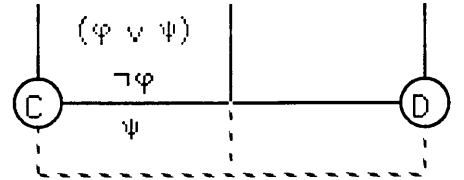
C_∨E1



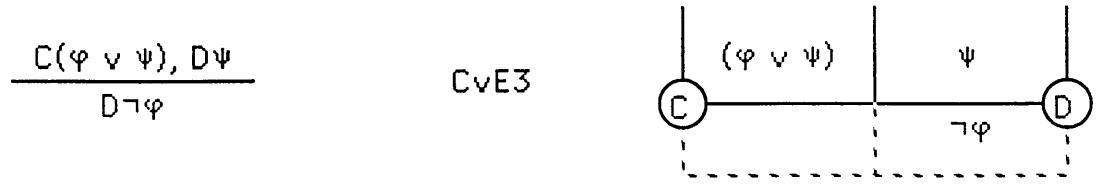
Rule C_∨E1 says that if one is committed to φ or ψ and committed to not ψ , then one is committed to φ .

$$\frac{C(\varphi \vee \psi), C\neg\varphi}{C\psi}$$

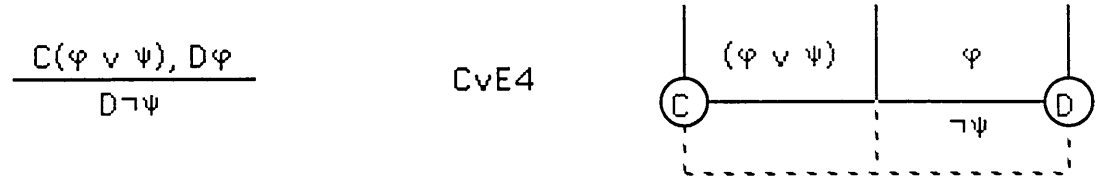
C_∨E2



If I'm committed to being *a good citizen or a parent*, and I'm committed to not being *a good citizen*, then I'm committed to being *a parent*.

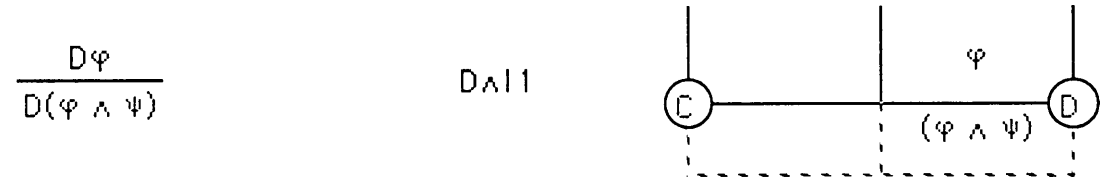


Rule $C\vee E3$ says that if one is committed to φ or ψ and not committed to ψ , then one is not committed to not φ .

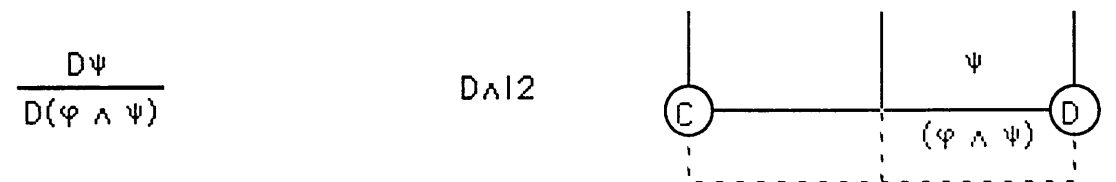


If I'm committed to being *a good citizen* or *a parent*, and I'm not committed to being *a good citizen*, then I'm not committed to not being *a parent*.

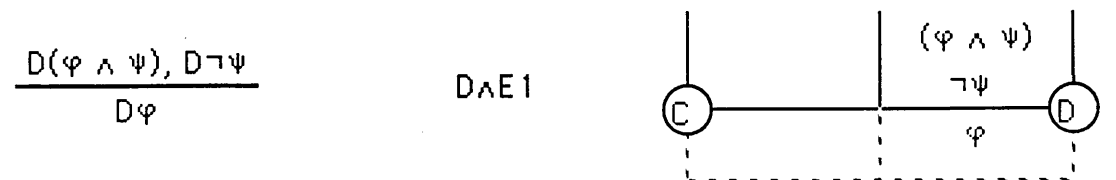
$D\wedge$



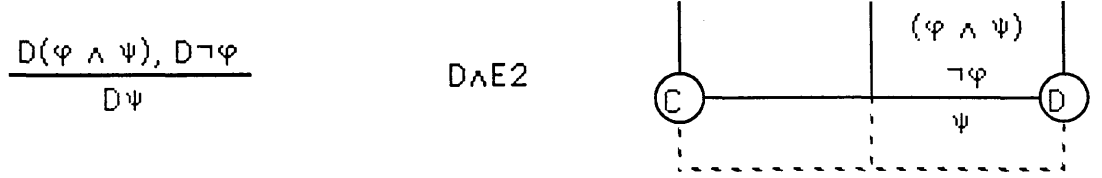
Rule $D\wedge I1$ says that if one is not committed to φ , then one is not committed to φ and ψ .



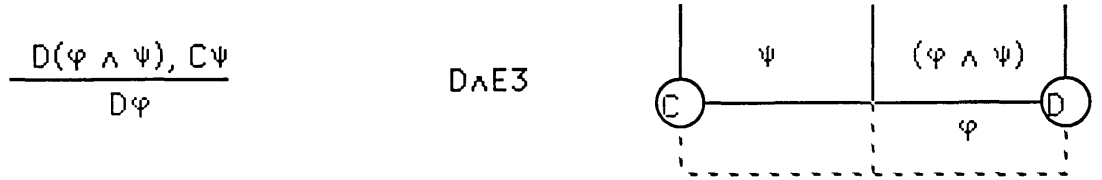
If I'm not committed to being *a parent*, then I'm not committed to being *a good citizen* and *a parent*.



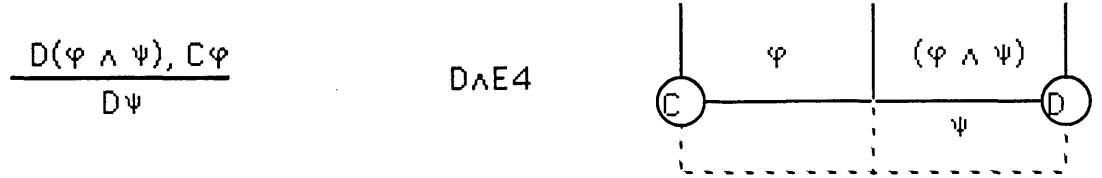
Rule $D\wedge E1$ says that if one is not committed to ϕ and ψ and not committed to not ψ , then one is not committed to ϕ .



If I'm not committed to being a *good citizen* and a *parent*, and I'm not committed to not being a *good citizen*, then I'm not committed to being a *parent*.



Rule $D\wedge E3$ says that if one is not committed to ϕ and ψ and committed to ψ , then one is not committed to ϕ .

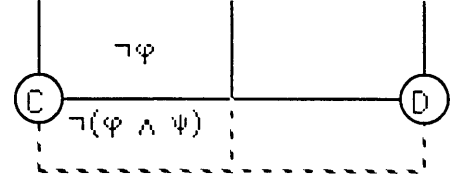


If I'm not committed to being a *good citizen* and a *parent*, and I'm committed to being a *good citizen*, then I'm not committed to being a *parent*.

The two sets of rules above $C\vee$ and $D\wedge$ are not duals because of the differences between rules $C\vee E3$ and $D\wedge E3$ ($C\vee E4$ and $D\wedge E4$). The asymmetry between these rules is caused by the need to weaken rules $D\wedge E$. To have them as perfect duals, their conclusions have to be of the form $C\neg\phi$ (or $C\neg\psi$), which would put ourselves in the position of, from not being committed to something to becoming committed to its opposite. For example, if one is not committed to being a good citizen, this does not imply one being committed to being a bad citizen. The opposite is fine: if one is committed to being a bad citizen, then one is not committed to being a good citizen. Therefore, we transform $C\neg\phi$ into $D\phi$ ($C\neg\phi$ in $D\psi$), which is justified by rule $D\neg I$ below.

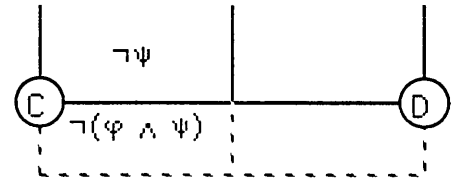
$C_{\neg\wedge}$

$$\frac{C\neg\varphi}{C\neg(\varphi \wedge \psi)}$$

 $C_{\neg\wedge I1}$ 

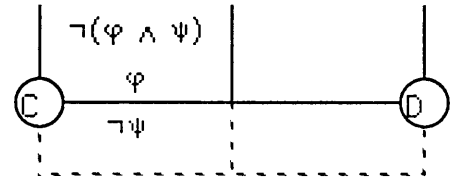
Rule $C_{\neg\wedge I1}$ says that if one is committed to not φ , then one is committed to not φ and ψ .

$$\frac{C\neg\psi}{C\neg(\varphi \wedge \psi)}$$

 $C_{\neg\wedge I2}$ 

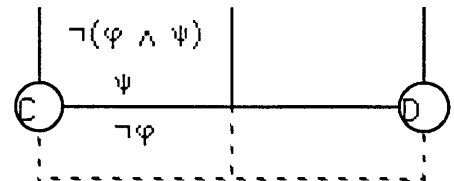
If I'm committed to not being a *parent*, then I'm committed to not being a *good citizen* and a *parent*.

$$\frac{C\neg(\varphi \wedge \psi), C\varphi}{C\neg\psi}$$

 $C_{\neg\wedge E1}$ 

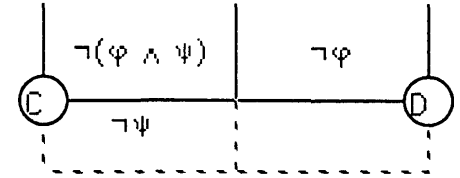
Rule $C_{\neg\wedge E1}$ says that if one is committed to not φ and ψ and committed to φ , then one is committed to not ψ .

$$\frac{C\neg(\varphi \wedge \psi), C\psi}{C\neg\varphi}$$

 $C_{\neg\wedge E2}$ 

If I'm committed to not being a *parent* and a *good citizen*, and committed to being a *good citizen*, then I'm committed to not being a *parent*.

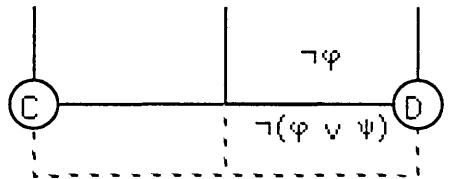
Next we indicate how rule $*C_{\neg\wedge E3}$ (and rule $*C_{\neg\wedge E4}$) would look and show the reasons for not having it (them).

$$\frac{C\neg(\varphi \wedge \psi), D\neg\varphi}{C\neg\psi} \quad *C\neg\wedge E3*$$


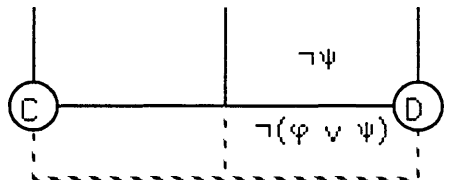
If I'm committed to not being *a parent* and *a good citizen*, and not committed to not being *a parent*, then I'm committed to not being *a good citizen*.

Although the reading that we gave to this rule makes it sound reasonable, there is some strengthening of commitments embedded in it that we want to avoid in the calculus. A formula in the D-store is influencing the conclusion of a formula in the C-store.

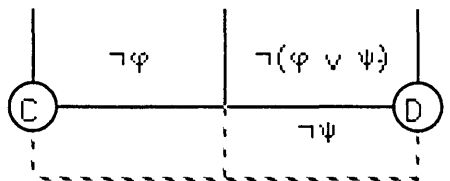
$D\neg\vee$

$$\frac{D\neg\varphi}{D\neg(\varphi \vee \psi)} \quad D\neg\vee I1$$


Rule $D\neg\vee I1$ says that if one is not committed to not φ , then one is not committed to neither φ nor ψ .

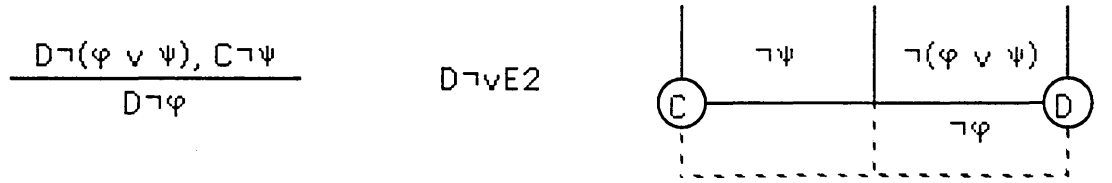
$$\frac{D\neg\psi}{D\neg(\varphi \vee \psi)} \quad D\neg\vee I2$$


If I'm not committed to not being *a parent*, then I'm not committed to neither being *a good citizen* nor *a parent*.

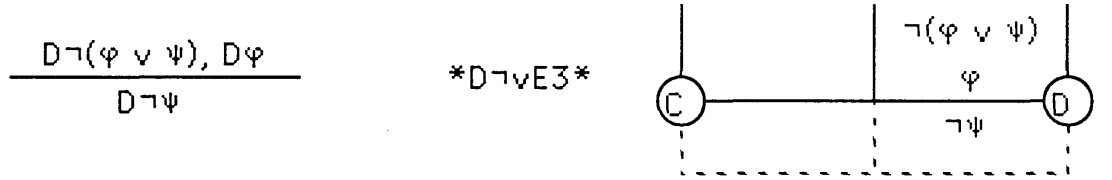
$$\frac{D\neg(\varphi \vee \psi), C\neg\varphi}{D\neg\psi} \quad D\neg\vee E1$$


Rule $D\neg\vee E1$ says that if one is not committed to neither φ nor ψ and committed to not φ , then one is not committed to not ψ .

Rule $D\neg\vee E1$ is not so straightforward. First imagine that you are committed not to go to the cinema or to the club. Next you decide to *relax* this commitment and withdraw it (which is similar to the effect caused by double negation in natural language). As a result of it, now you are not committed not to go to the cinema or to the club. Then you remember that you are committed not to go to the cinema because you simply hate black and white movies and there is no colour movie showing in town. You conclude that you are not committed not to go to the club, i.e. there is a chance that you might end up dancing to the sound of lambada but you are definitely not going to watch any movie this evening.



Next we indicate how rule $*D\neg\vee E3*$ (and rule $*D\neg\vee E4*$) would look and show the reasons for not having it (them).

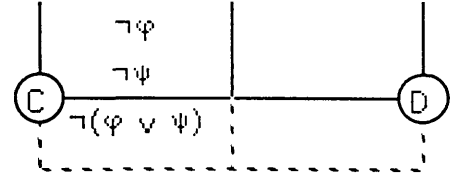


Now instead of being committed not to go to the cinema, you are simply not committed to go to the cinema. We feel that the conclusion is a bit too strong to follow from the premisses, therefore we do not want to have the rule $*D\neg\vee E3*$ in our calculus.

The two sets of rules $C\neg\wedge$ and $D\neg\vee$ above are asymmetric in the sense that both sets of rules lack their counterparts. Rules $C\neg\wedge E1$ and $C\neg\wedge E2$ miss their duals which are rules $*D\neg\vee E3*$ and $*D\neg\vee E4*$ respectively. The same happens to rule $D\neg\vee E1$ and rule $D\neg\vee E2$ which miss their dual rules $*C\neg\wedge E3*$ and $*C\neg\wedge E4*$ respectively.

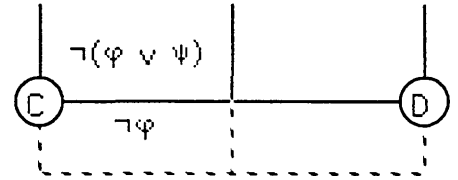
C $\neg\vee$

$$\frac{C\neg\varphi, C\neg\psi}{C\neg(\varphi \vee \psi)}$$

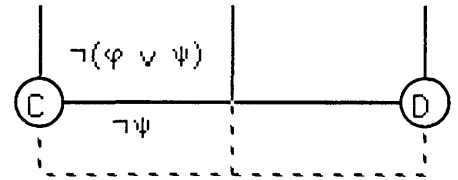
C $\neg\vee$ I

Rule C $\neg\vee$ I says that if one is committed to not φ and committed to not ψ , then one is committed to not φ or ψ .

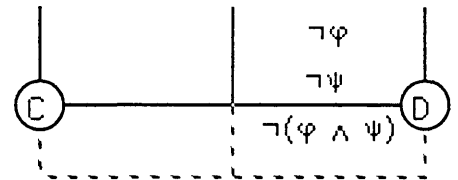
$$\frac{C\neg(\varphi \vee \psi)}{C\neg\varphi}$$

C $\neg\vee$ E1

$$\frac{C\neg(\varphi \vee \psi)}{C\neg\psi}$$

C $\neg\vee$ E2**D $\neg\wedge$**

$$\frac{D\neg\varphi, D\neg\psi}{D\neg(\varphi \wedge \psi)}$$

D $\neg\wedge$ I

Rule D $\neg\wedge$ I says that if one is not committed to not φ and not committed to not ψ , then one is not committed to not φ and ψ .

If I'm not committed to not being a *good citizen* and not committed to not being a *parent*, then I'm not committed to not being a *good citizen* and a *parent*.

$$\frac{D\neg(\varphi \wedge \psi)}{D\neg\varphi} \quad D\neg\wedge E1$$

If I'm not committed to not being *a good citizen* and *a parent*, then I'm not committed to not being *a good citizen*.

$$\frac{D\neg(\varphi \wedge \psi)}{D\neg\psi} \quad D\neg\wedge E2$$

The two sets of rules above $C\neg\vee$ and $D\neg\wedge$ are duals. This implies that the rules for dealing with disjunctions of negative commitments are similar to the rules for dealing with conjunctions of negative D-commitments.

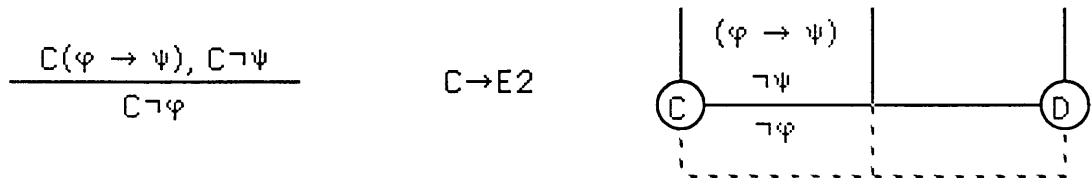
The following rules give *identity* to this commitment calculus. They are not just *bureaucratic* symbol manipulation but actually *mean* something. Moreover, the absence of counterparts for some of the rules below indicate a lot about the interaction between this calculus and the reasoning system developed in the next chapter.

$C\rightarrow$

$$\frac{C(\varphi \rightarrow \psi), C\varphi}{C\psi} \quad C\rightarrow E1$$

If Joan has a commitment to the idea that being *a married person* implies being *a mother*, and Joan has a commitment to becoming *a married person*, then Joan has a commitment to becoming *a mother*.

This rule captures an important valid formula $\{C\varphi \wedge C(\varphi \rightarrow \psi) \rightarrow C\psi\}$ in the commitment logic that we wanted to preserve.

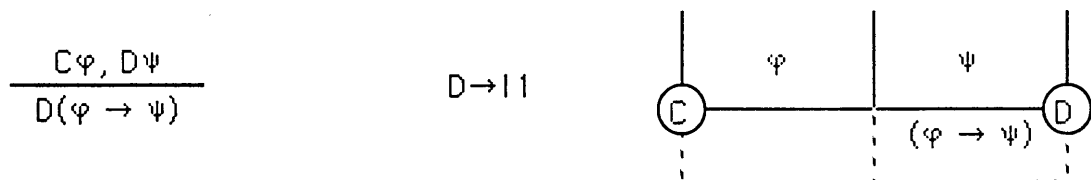


If Joan has a commitment to the idea that being a *married person* implies being a *mother*, and Joan has a commitment to not becoming a *mother*, then Joan has a commitment to not becoming a *married person*.

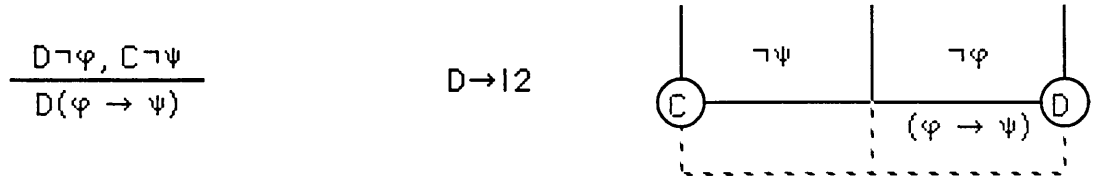
One would expect to find at this point a rule like $C\rightarrow I$: a rule that would create conditional commitments from individual commitments. Nevertheless, conditionals will only appear in the commitment store as the result of the assertion of a conditional or as the result of a justification for a challenge. It is the *argumentation step*.

The following two rules, although introducing conditionals, do not contradict what we just said above. What they tell us is that given that one has the stated formulas in one's commitment store, *it would be dangerous* for one to become committed to the stated conditional, because one will be introducing a contradiction in one's store, hence becoming liable to a resolution demand from the other party to put the record straight.

D→



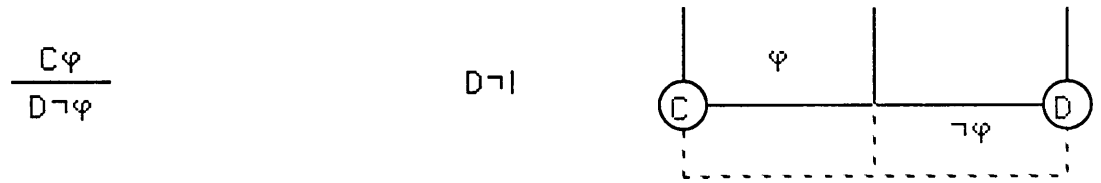
If Joan has a commitment to becoming a *married person*, and Joan does not have a commitment to becoming a *mother*, then *it would be dangerous* for Joan to become committed to the idea that being a *married person* implies being a *mother*.



If Joan does not have a commitment to not becoming a *married person*, and Joan has a commitment to not becoming a *mother*, then *it would be dangerous* for Joan to become committed to the idea that being a *married person* implies being a *mother*.

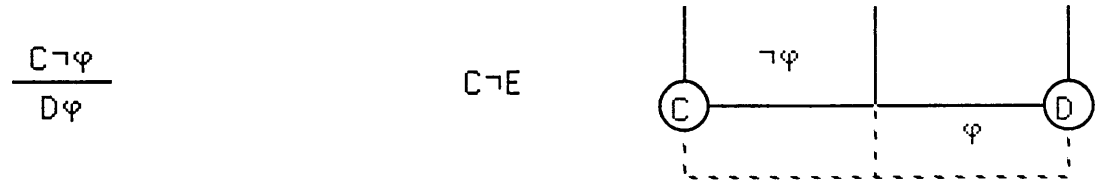
The two rules below show how formulas can move from the C-store to the D-store. It is perceivable from them that this move - from 'C' to 'D' - implies the same sort of relaxation that occurs in natural language provided by the double negation.

D¬



If I'm committed to being a *good citizen*, then I'm not committed to not being a *good citizen*.

C¬

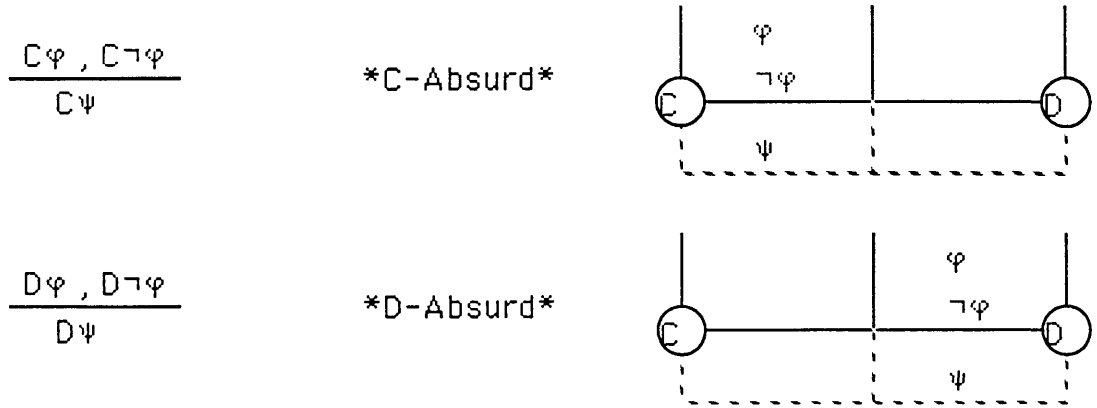


If Joan has a commitment to not becoming a *married person* then Joan does not have a commitment to becoming a *married person*.

This rule captures an important valid formula $\{C\neg\varphi \rightarrow \neg C\varphi\}$ in the commitment logic that we wanted to preserve - allowing commitments to be weakened. We do not have rule $D\varphi/C\neg\varphi$. Thus, this preserves another important aspect of commitment logic - not allowing

commitments to be strengthened - in which $\{\neg C\phi \rightarrow C\neg\phi\}$ is not a valid formula.

Finally we do not have the following rules in our calculus. This way we avoid the generation of undesirable implicit commitments from two contradictory explicit ones.



Based on the rules given above, a definition for a commitment calculus derivability ($\vdash_{CC}$) is given below:

$\Gamma \vdash_{CC} \phi$ iff

$\exists \phi_1, \phi_2, \dots, \phi_n$ where

$\phi = \phi_n$ and

for each $i, i = 1$ to $n, \phi_i \in \Gamma$ or

was obtained through applications of CC rules.

6.4. Commitment-Consistency

The soundness of this calculus is a trivial result. Regarding completeness of this calculus, we feel that it falls outside the scope of this work. We are still investigating the subject and we do not feel that it is necessary to present a full account of the calculus at this stage. Nevertheless, the present version of the calculus is strong enough to deal with all the aspects brought up in this dissertation.

In this section we show that the calculus is commitment-consistent, to disband any fears that the calculus falls into some contradiction at the propositional level.

We say that this calculus is commitment-consistent, because starting from commitment-consistent commitment stores and using only the rules supplied by the calculus, we never derive both that we are committed to something and to the negation of that thing ($C\phi$, $C\neg\phi$).

Commitment-Consistency is defined based on the strongest case which is $(D\phi, D\neg\phi)$. This is the case, because in CC premisses in the D-stores can never influence conclusions that appear in the D-stores, the opposite being permitted.

Definition: *Commitment-Consistency*

$C\Gamma \cup D\Delta$ is commitment-consistent iff it is not the case that
 $(C\Gamma, D\Delta \vdash_{cc} D\phi$ and $C\Gamma, D\Delta \vdash_{cc} D\neg\phi)$.

Based on this definition of commitment-consistency we have two immediate results:

Immediate Result 1:

If $C\Gamma \cup D\Delta$ is commitment-consistent then it is not the case that
 $(C\Gamma, D\Delta \vdash_{cc} C\phi$ and $C\Gamma, D\Delta \vdash_{cc} D\phi)$.

Proof: Suppose that $C\Gamma \cup D\Delta$ is commitment-consistent and it is the case that $C\Gamma, D\Delta \vdash_{cc} C\phi$ and $C\Gamma, D\Delta \vdash_{cc} D\phi$.

Then applying rule $D\neg$ in section 6.3. to $C\Gamma, D\Delta \vdash_{cc} C\phi$ we have $C\Gamma, D\Delta \vdash_{cc} D\neg\phi$ which contradicts the definition of commitment-consistency.

Immediate Result 2:

If $C\Gamma \cup D\Delta$ is commitment-consistent then it is not the case that
 $(C\Gamma, D\Delta \vdash_{cc} C\phi$ and $C\Gamma, D\Delta \vdash_{cc} C\neg\phi)$.

Proof: Suppose that $C\Gamma \cup D\Delta$ is commitment-consistent and it is the case that $C\Gamma, D\Delta \vdash_{cc} C\phi$ and $C\Gamma, D\Delta \vdash_{cc} C\neg\phi$.

Then applying rule $D\neg$ in section 6.3. to $C\Gamma, D\Delta \vdash_{cc} C\phi$ we have

$C\Gamma, D\Delta \vdash_{cc} D\neg\phi$, and

Applying rule $C\neg$ in section 6.3. to $C\Gamma, D\Delta \vdash_{cc} C\neg\phi$ we have

$C\Gamma, D\Delta \vdash_{cc} D\phi$,

which contradicts the definition of commitment-consistency.

Using similar techniques to Hughes and Cresswell's (1968) we show that CC is commitment-consistent.

Theorem: If $C\Gamma, D\Delta$ is not commitment-consistent
 then $\Gamma, \neg\Delta$ is inconsistent in PC (propositional calculus).

Proof: Suppose that $C\Gamma, D\Delta$ is not commitment-consistent.

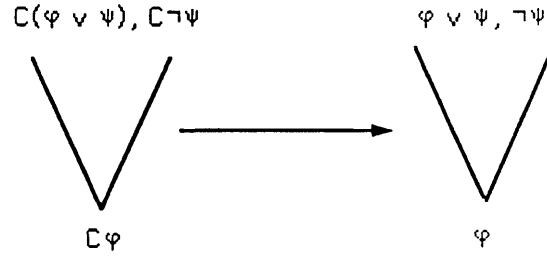
Therefore $\exists\phi$ such that $C\Gamma, D\Delta \vdash_{cc} D\phi$ and $C\Gamma, D\Delta \vdash_{cc} D\neg\phi$.

For every wff of CL we construct its PC-transform the following way:

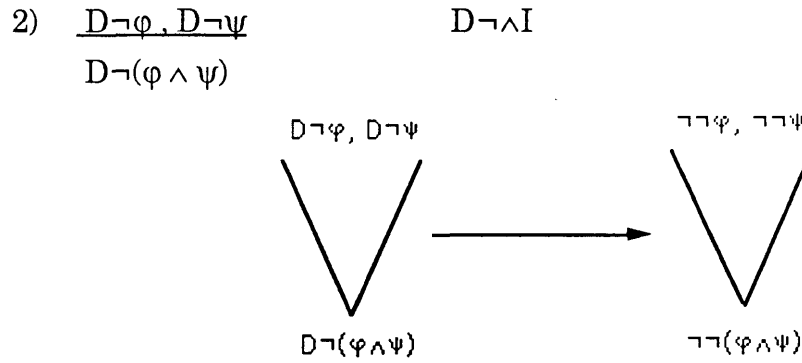
- 1) Deleting C's;
- 2) Replace D's by $\neg$'s.

For each rule of CC we see by transforming the premisses and conclusions, that we end up with a valid rule of PC. Below we present two examples of CC rules transformed into PC rules:

- 1)
$$\frac{C(\phi \vee \psi), C\neg\psi}{C\phi} \quad C\vee E1$$



Where $\frac{(\varphi \vee \psi), \neg\psi}{\varphi}$ is very similar to one of the ' $\vee$ ' elimination rules for propositional calculus using natural deduction style.



Where $\frac{D\neg\varphi, D\neg\psi}{D\neg(\varphi \wedge \psi)}$ becomes $\frac{\varphi, \psi}{\varphi \wedge \psi}$ which is very similar to the ' $\wedge$ ' introduction rule for propositional calculus using natural deduction style.

So by induction, any proof in CL can be transformed into a proof in PC.

So by transforming $C\Gamma, D\Delta \vdash_{CC} D\varphi$ we have $\Gamma, \neg\Delta \vdash_{PC} \neg\varphi$ and
by transforming $C\Gamma, D\Delta \vdash_{CC} D\neg\varphi$ we have $\Gamma, \neg\Delta \vdash_{PC} \neg\neg\varphi$.

So $\Gamma, \neg\Delta$ is inconsistent in PC.

6.5. Summary

In the previous chapter we revisited the notion of commitment and proposed a Framework for Dialogue Reasoning Systems consisting of a Commitment Calculus (CC) and a Commitment Action Dialogue Reasoning System (CADReS).

In this chapter we developed the aforementioned Commitment Calculus for dealing with the consequences of commitments inside the commitment stores. Its rules envisage consistency preservation inside the commitment stores. Each party has a commitment store for its positive and negative commitments ('C' commitment store), and a 'D' commitment store as a place for the statements which the party is not committed to. We decided to design the stores in this way, because it is very revealing about the three-valued nature of our notion of commitment. We are not interested in giving a definitive meaning to the notion of commitment, but solely providing a framework within which to operate it. Our treatment of commitment is based on the discussion developed in the previous chapters.

The semantics of this calculus is based on the notion of commitment membership, i.e. the truth and falsity of formulas is defined by their membership status in the commitment stores. The soundness of this calculus is a trivial result.

Given that we are still experimenting with it, there is no full account of the calculus yet. Thus we did not contemplate giving it a completeness result. Nevertheless, we proved the calculus to be commitment-consistent, showing in this way that it does not fall into a contradiction at the propositional level.

The commitment calculus however, gives only a static view of commitment. We therefore embed this calculus into a dialogue system which gives a dynamic view of the way that commitments are established and discharged.

Finally, the importance of this calculus to our framework is justified in

the next chapter because of its relevance to the locution modifier Resolution Demand. For its specification the commitment calculus has to be taken into account. A party is only allowed to urge the other party to straighten its commitment store, if by the sole application of a commitment calculus rule, the latter's commitment store is proved to be contradictory. If the condition above is not met, the dialogue will be brought to an error state.

Chapter 7

Commitment Action Dialogue Reasoning System

A Commitment Action Dialogue Reasoning System (CADReS) is proposed in this chapter. It has axioms of the form $\{Pre \rightarrow [Party_A to Party_B, Locutions] Post\}$, where $Party_A$ and $Party_B$ are the participants in the dialogue and $Locutions$ are the application of a finite set of locution modifiers to statements. Pre and $Post$ are the pre- and post-conditions of the locutions performed by party.

The Commitment Calculus developed in the previous chapter, introduces the semantics and the rules for the manipulation of these pre- and post-conditions. Its interaction with CADReS is presented in this chapter.

At the current stage of this work CADReS only provides us with representation schemes. We do not have reasoning strategies for its animation yet. However, given that in the future we wish to deal with the normative aspects of arguments (valid or invalid, good or bad), we have already incorporated some notions - the *health* state of the commitment stores - in CADReS.

7.1. CADReS Axioms

In respect of our framework, CADReS is responsible for the insertion/deletion of commitments in the commitment stores (see figure 5.2 in section 5.5.). To capture this mechanism we defined it in an axiomatic way using a modal [action] logic style (Goldblatt 1982, Maibaum 1987).

Its axioms are divided into two different sets: commitment and legality axioms. Commitment axioms define the changes in the commitment stores and the *health* of the post-conditions caused by the uttering of each specific locution. These axioms essentially have the format:

Pre $\rightarrow$ [AtoB, Locution] Post

After Party_A uttered Locution to Party_B, then given Pre happens to be the case prior to Locution, Post happens to be the case after Locution.

Legality axioms define the proper ordering for uttering locutions. Their general shape is:

Pre $\rightarrow$ [AtoB, Locution] [BtoA, Locution'] Post

After Party_A uttered Locution to Party_B and Party_B uttered Locution' to Party_A, then given Pre happens to be the case prior to Locution, Post happens to be the case after Locution'.

At the current stage of this work our dialogues are limited to two parties. However, in the future we would like to extend our framework from two-party to N-party. This justifies the sense of direction given to our locutions: AtoB (from Party_A to Party_B). A possible extension could look like: AtoAudience (from Party_A to Audience) or AtoB_C_D (from Party_A to Parties_B_C_D) which constitutes a qualified audience.

7.1.1. Language for Pre- and Post-conditions

The elements and the rules that form and control the pre- and post-conditions of CADReS are those defined for the Commitment Calculus. For CADReS these boundary conditions and the commitment stores are one and the same thing. However, at this level, two new states of affairs are defined - *healthy* and *error* - (remember that commitment stores define s-o-a's) that would be rendered meaningless at the commitment calculus level.

Let us define 'P' - the language of pre- and post-conditions - by extending the language definition in the commitment calculus.

Definition: *Language L'*

Let L' be the propositional language:
 $p, q, .. \in L'$ (atomic propositions)
 If $\phi, \psi \in L'$ then $\neg\phi, \phi \wedge \psi, \phi \vee \psi, \phi \rightarrow \psi \in L'$.

Definition: *Language P*

Let P be the language of pre- and post-conditions:
 If $\phi \in L'$ then $\phi, C\phi, D\psi$, healthy, error and ' $\wedge$ ' $\in P$.

Definition: $C\Gamma = \{C\phi \mid \phi \in \Gamma\}$

Definition: $D\Delta = \{D\phi \mid \phi \in \Delta\}$

Healthy indicates that the dialogue has been played properly until that stage, thus the commitment stores are in good condition. So, empty stores make for healthy conditions. At this point we might be encouraged to think that a party's store describing a contradictory s-o-a, e.g. $(C_a\phi \wedge C_a\neg\phi)$, does not make for a healthy condition, but that is misleading. In the case above, it will be at the other party's discretion to ask Party_A to straighten up its store. Nothing is wrong with the pre- or post-condition.

Error indicates that there is something wrong with the conditions, therefore with the dialogue. In the commitment case, an error state occurs when a party chooses a locution that does not match with the given pre-condition. In the legality case, an improper sequencing of locutions leads to an error. At the current stage of this work, whenever an error state occurs, 'error' is placed in the speaker's commitment store - the one responsible for causing the error state. Otherwise, both commitment stores remain the same.

7.1.2. Locution Modifiers

This section introduces some axioms that characterise each of the following locution modifiers: Assertion, Question, Withdrawal, Challenge, Justification (Justification for the Challenge of an Implication), Denial and Resolution Demand.

Concerning the commitment case, the only changes in the commitment stores are those that appear in the axioms, the rest remains the same. It also presents situations where the uttering of some specific locution under certain pre-conditions leads to an *error* post-condition.

Concerning the legality case, we are only interested in capturing which sequences involving each specific locution modifier lead to an error or healthy post-condition - we always start from a healthy pre-condition. We first present all the sequences which have that specific locution modifier as the first member, then we present the axioms that end with it.

Special attention is given to the locution modifier Resolution Demand. For its specification the commitment calculus has to be taken into account. A party is only allowed to urge the other party to straighten his (the other party's) commitment store, if by the sole application of a commitment calculus rule, the latter's commitment store is proved to be contradictory. If the condition above is not met, the speaker - the one who demanded the resolution - will bring about an error state. For the sake of clarity, when we present its legality axioms, we assume that the

contradiction is in the 'C' store.

As to the choice for the locution modifiers, it was in some sense an arbitrary one. We followed Mackenzie's choice, except for the locution modifier *justification* (and *justification for the challenge of an implication*) which we introduced. We also treat some of the other locution modifiers in a slightly different way - we grant denial the full status of a locution modifier and we only provide for one version of resolution demand. Mackenzie's choice was influenced by Hamblin's selection, which we believe was inspired by the ancient game of *Obligation*, performed in the *Academy*, a garden near Athens where Plato and Aristotle used to teach.

The reader should always have in mind that our aim is to develop a framework for dialogue reasoning systems and not the specification of a finished dialogue logic, multi-purpose and ready for use. For each different application, a purpose built dialogue system should be set up and each rule or axiom tailored for its specific task. We believe that this feeling also pervades Mackenzie's work. In his article *Four Dialogue Systems* (Mackenzie 1990), he introduces the locution modifier *Hunches* ('I guess that P') and uses the notion of *Balk* in addition to that of commitment. The message could not be more clear, the framework is there to build on it. There is a lot of work done in the theory of speech acts (Austin 1962, Searle 1969, Searle 1979, Searle & Vanderveken 1987), that could be related to the nature of the locution modifiers used here but at the current stage of this work the former is not particularly relevant.

Finally, it is important to remember that locution modifiers should be seen in context, i.e. while interacting with each other. This was done when we applied the dialogue formalism to software specification. In the following sub-sections we first look at them individually, trying to bring out some of the common sense embedded in each of them. For each of them we introduce some commitment and legality axioms. At the end of the chapter we combine them, showing in this way that they are expressive enough to emulate some patterns of reasoning which are common in cooperative environments.

7.1.2.1. Languages for locution modifiers and CADReS

Before we start giving the axioms for each locution modifier, we present languages for locution modifiers and CADReS.

Definition: *Language* L_{Loc}

Let L_{Loc} be the language of locution modifiers:

if $\varphi \in L'$ then **asserts**(φ) $\in L_{Loc}$;

if $\varphi \in L'$ then **questions**(φ) $\in L_{Loc}$;

if $\varphi \in L'$ then **withdraws**(φ) $\in L_{Loc}$;

if $\varphi \in L'$ then **why**(φ) $\in L_{Loc}$;

if $\varphi \in L'$ then **justifies**(φ) $\in L_{Loc}$;

if $\varphi \in L'$ then **justIMP**(φ) $\in L_{Loc}$;

if $\varphi \in L'$ then **denies**(φ) $\in L_{Loc}$;

if $C\varphi, C\psi, C\gamma$ and ' $\wedge$ ' $\in P$ then **resolve**($C\varphi \wedge C\psi / C\gamma$) $\in L_{Loc}$.

Definition: *Language* L_{CADReS}

Let L_{CADReS} be the language of CADReS:

if $pre \in P$ and $pos \in P$ and **Loc** $\in L_{Loc}$ then

$pre \rightarrow [AtoB, \mathbf{Loc}] pos \in L_{CADReS}$ and

$pre \rightarrow [BtoA, \mathbf{Loc}] pos \in L_{CADReS}$.

7.1.2.1.1. Assertion

The assertion of a statement commits the speaker and the hearer to the s-o-a (and to its immediate consequences, i.e. consequences inferred from the application of any rule of the commitment calculus once) described by that statement.

Language: **asserts**(s): It is the case that s.

Commitment Axioms

$\text{healthy} \rightarrow [\text{AtoB}, \text{asserts}(\varphi)] C_a\varphi \wedge C_b\varphi$

After Party_A uttered **asserts**(φ) to Party_B, then given that P is a healthy state prior to the assertion, both parties are committed to φ .

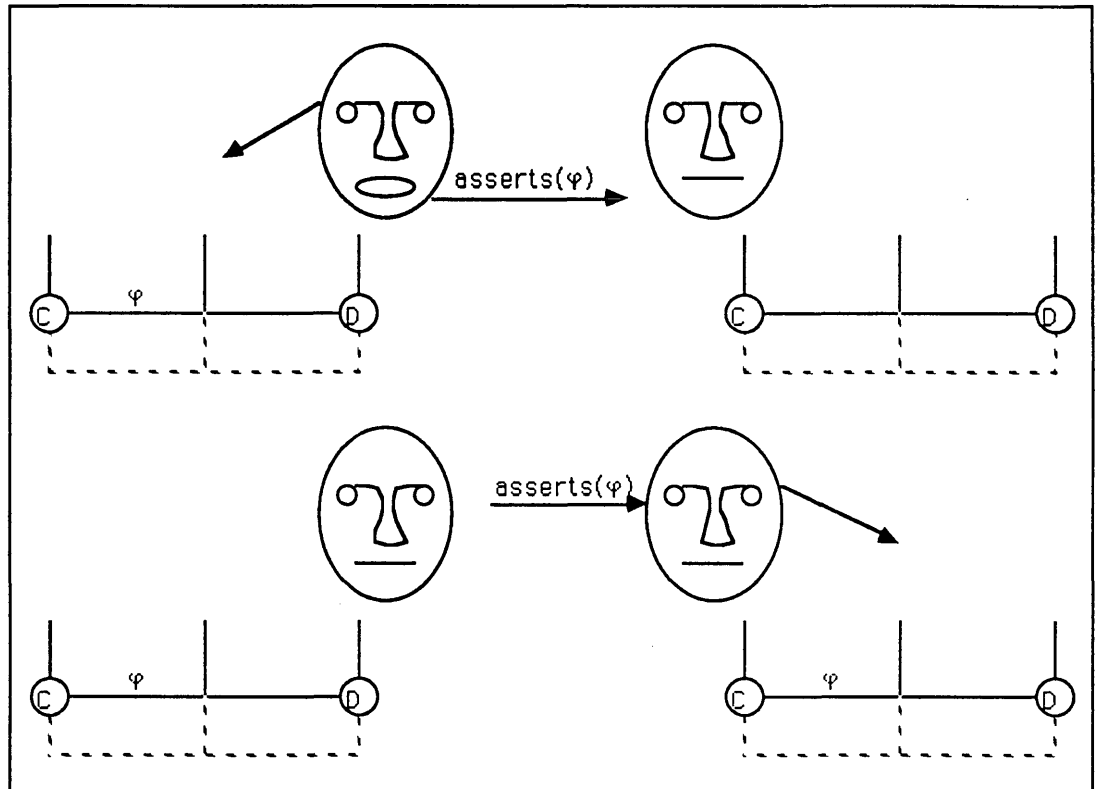


Figure 7.1 Talking Heads: Assertion I

A party is committed to anything stated by another party. The placing of a commitment inside the other party's store is a way to force him to react to it. Silence has the force of agreement so, if he does not react to it he becomes committed to it and to its immediate consequences. To get rid of a commitment (in its commitment store) Party_B has to withdraw (section 7.1.2.3) it. When given as an answer to a question (section 7.1.2.2.), an assertion is the same as confirmation or a yes.

$C_a\varphi \rightarrow [AtoB, \mathbf{asserts}(\varphi)] \text{ error}$

After Party_A uttered **asserts**(φ) to Party_B, then given that Party_A is committed to φ prior to the assertion, P' is an error state, both commitment stores remain the same.

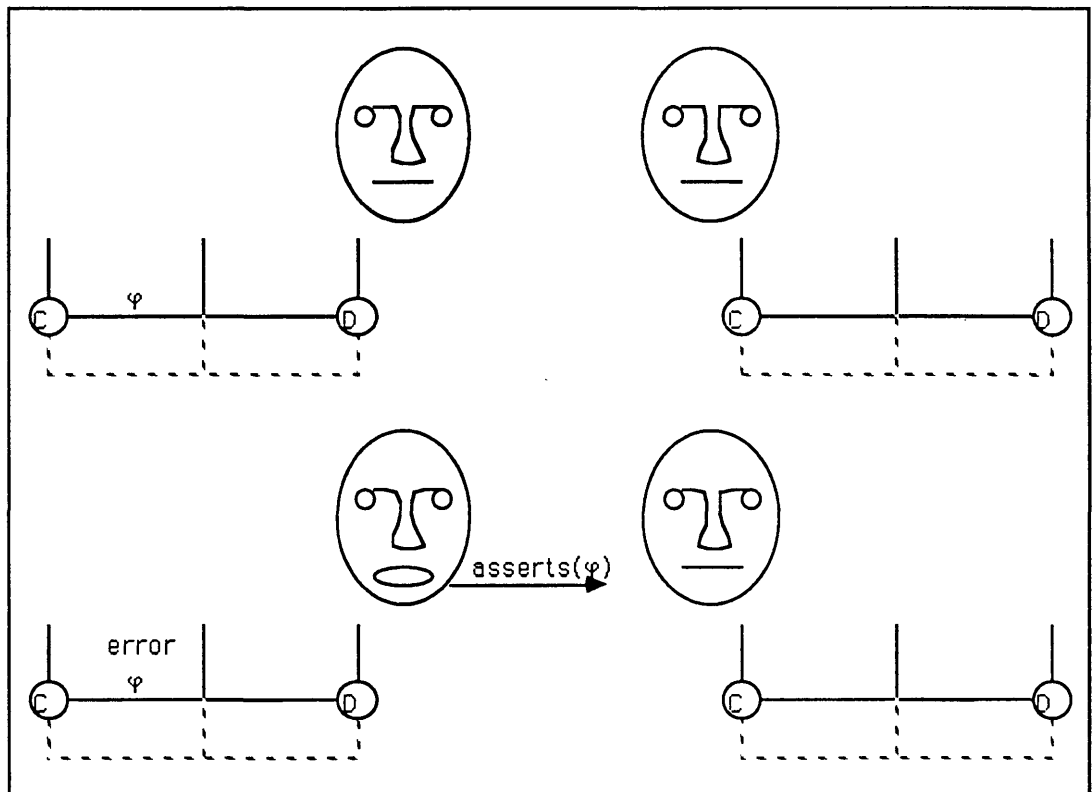


Figure 7.2 Talking Heads: Assertion II

One is not allowed to re-assert one's commitment. Being repetitive is not a *healthy* way to advance reasoning.

Legality Axioms

Starting with an assertion.

healthy to healthy

healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **questions**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **why**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **resolve**(C Γ /C ψ)] healthy

healthy to error

healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **denies**(ψ)] error
 healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **justifies**(ψ)] error

Ending with an assertion.

healthy to healthy

healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **justifies**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **denies**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **resolve**(C Γ /C ϕ)] [BtoA, **asserts**(ψ)] healthy

healthy to error

healthy $\rightarrow$ [AtoB, **why**(ϕ)] [BtoA, **asserts**(ψ)] error

7.1.2.1.2. Question

To question a statement is to doubt (the very existence) of the s-o-a described by that statement. It does not commit either speaker or hearer to the s-o-a described by the questioned statement.

Language: **questions(s)**: Is it the case that s?

Commitment Axioms

$\text{healthy} \rightarrow [\text{AtoB}, \text{questions}(\varphi)] \text{healthy}$

After Party_A uttered **questions**(φ) to Party_B, then given that P is a healthy state prior to the question, P' is a healthy state. Both commitment stores remain the same.

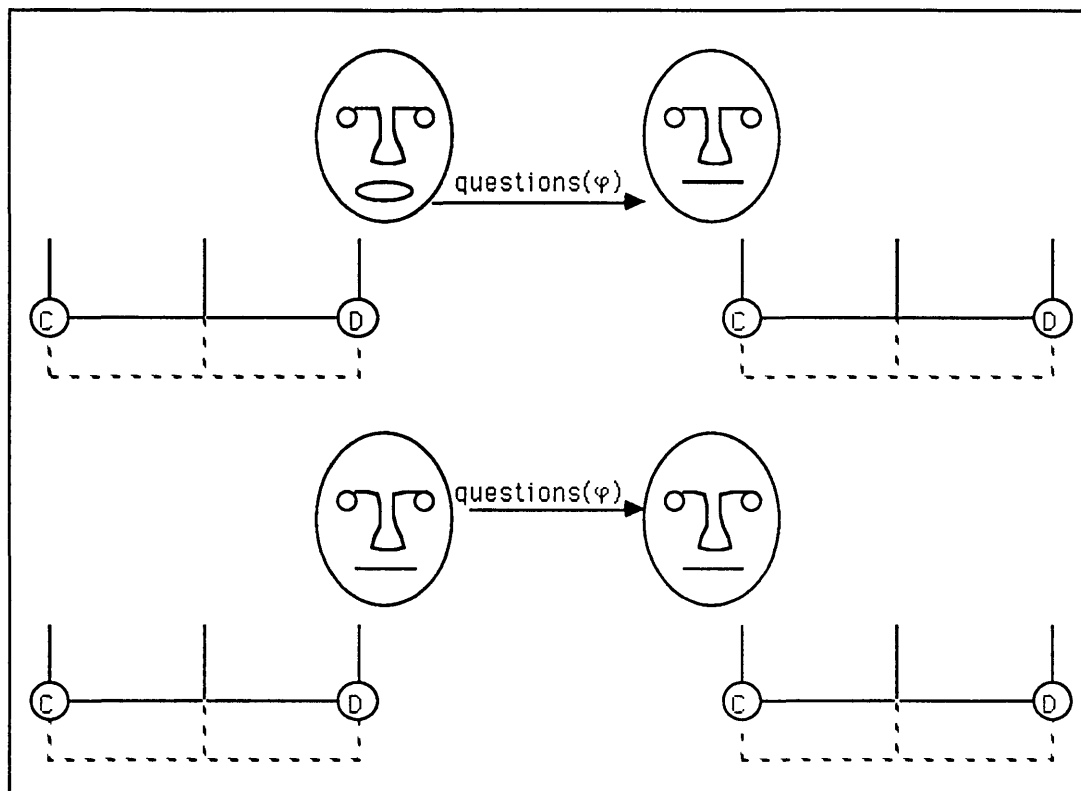


Figure 7.3 Talking Heads: Question I

The uttering of a question does not affect the commitment stores. After asking a question, it is up to the other party to confirm it, deny it (section 7.1.2.6.) or distance himself from it (withdraw it). The question answer mechanism is very useful for advancing the reasoning process. By means of it, conclusions are made available and common ground is established that way.

$C_a\phi \rightarrow [AtoB, \text{questions}(\phi)] \text{ error}$

After Party_A uttered **questions**(ϕ) to Party_B, then given that Party_A is committed to ϕ prior to the question, P' is an error state.

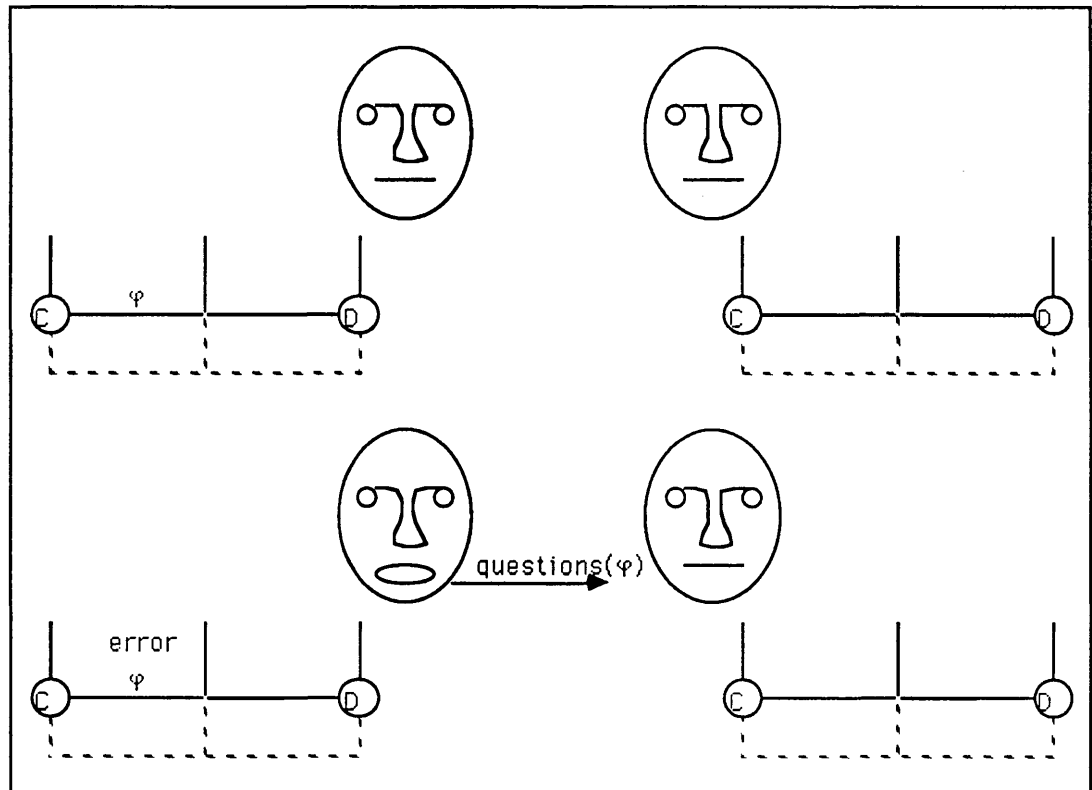


Figure 7.4 Talking Heads: Question II

One cannot question one's commitments. A party cannot doubt the existence of a commitment that is already in his commitment store, he can only withdraw it or challenge it (section 7.1.2.4.).

Legality Axioms

Starting with a question.

healthy to healthy

healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **denies**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **withdraws**(ψ)] healthy

healthy to error

healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **why**(ψ)] error
 healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **resolve**($C\Gamma/C\psi$)] error
 healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **questions**(ψ)] error
 healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **justifies**(ψ)] error

Ending with a question.

healthy to healthy

healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **questions**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **questions**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **justifies**(ϕ)] [BtoA, **questions**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **denies**(ϕ)] [BtoA, **questions**(ψ)] healthy

healthy to error

healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **questions**(ψ)] error
 healthy $\rightarrow$ [AtoB, **why**(ϕ)] [BtoA, **questions**(ψ)] error
 healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **questions**(ψ)] error

For future extensions on the subject of *questions*, there is a vast literature that we will take into consideration - notably *New Foundations for a Theory of Questions and Answers* (Hintikka 1983), *The Logic of Questions* (Harrah 1984) and *On Questions* (Hoepelman 1983).

7.1.2.1.3. Withdrawal

To withdraw a statement is to dissociate oneself from the s-o-a described by that statement. Nevertheless it is not just a rejection of a statement, because now the speaker is aware of it. To mark this difference, the statement is placed in the 'D' part of the commitment store. If the speaker was committed to that statement previously to its withdrawal, after the withdrawal he (she) is not committed to it any more.

Language: **withdraws**(s): I am not so sure that s
or No commitment to s.

Commitment Axioms

$C_a\phi \rightarrow [AtoB, \text{withdraws}(\phi)] D_a\phi$

After Party_A uttered **withdraws**(ϕ) to Party_B, then given that Party_A is committed to ϕ prior to the withdrawal, A is not committed to ϕ .

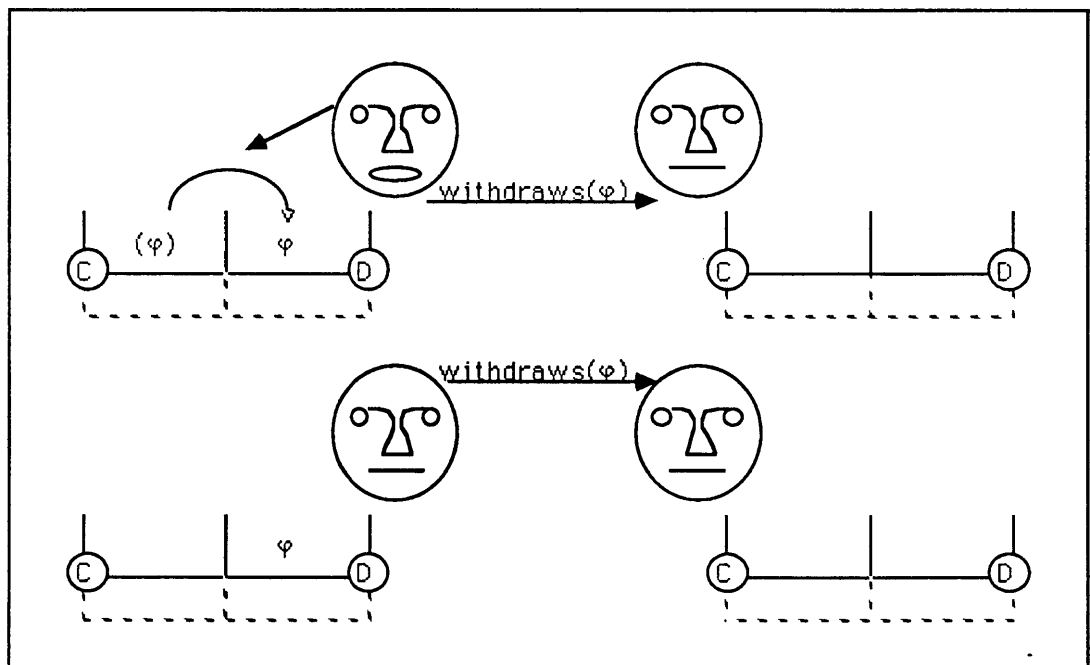


Figure 7.5 Talking Heads: Withdrawal I

The situation pictured above typifies the way that a party gets rid of a commitment that was probably - but not exclusively - placed there as the

result of an assertion uttered by the other party.

$\text{healthy} \rightarrow [\text{AtoB}, \text{withdraws}(\varphi)] D_a\varphi$

After Party_A uttered **withdraws**(φ) to Party_B, then given that P is a healthy state prior to the withdrawal, Party_A is not committed to φ .

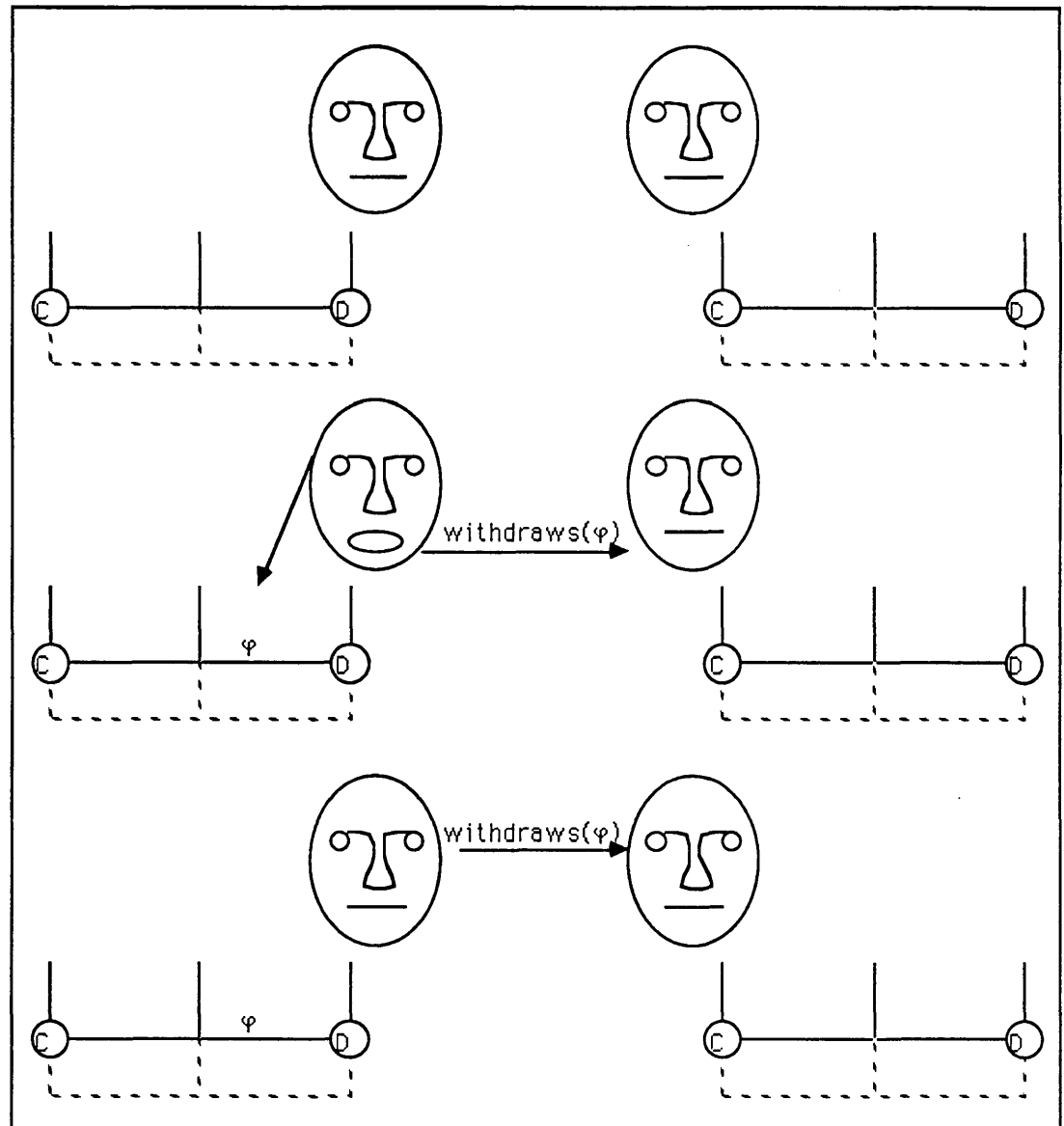


Figure 7.6 Talking Heads: Withdrawal II

The situation above reflects the awareness of the s-o-a that comes from a comment like *I am not so sure that*. It is weaker than a commitment to the negation of the same s-o-a.

$D_a\phi \rightarrow [AtoB, \mathbf{withdraws}(\phi)] \text{ error}$

After Party_A uttered **withdraws**(ϕ) to Party_B, then given that Party_A is not committed to ϕ prior to the withdrawal, P' is an error state.

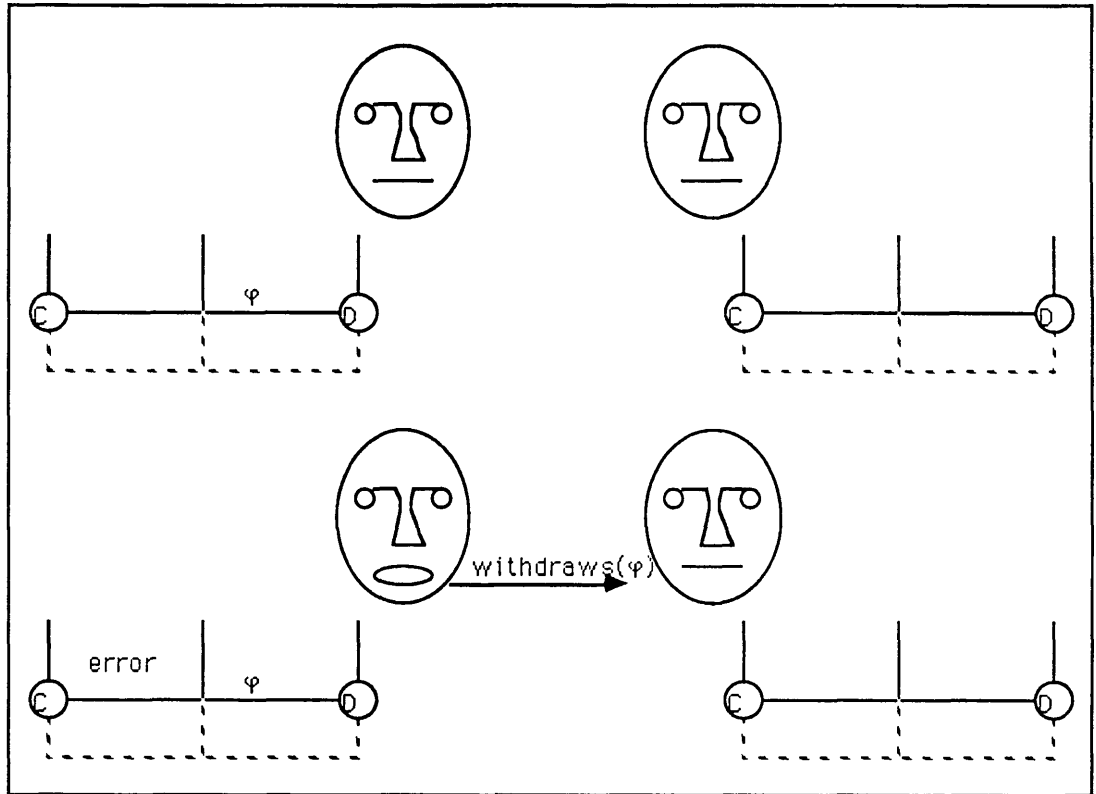


Figure 7.7 Talking Heads: Withdrawal III

One cannot withdraw what one has withdrawn before. We do not provide a mechanism for *forgetting* in our framework. This axiom stresses the *awareness* aspect given to our notion of commitment.

Legality Axioms

Starting with a withdrawal.

healthy to healthy

healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **why**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **resolve**(C Γ /C ψ)] healthy
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **questions**(ψ)] healthy

healthy to error

healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **denies**(ψ)] error
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **justifies**(ψ)] error

Ending with a withdrawal.

healthy to healthy

healthy $\rightarrow$ [AtoB, **asserts**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **questions**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **withdraws**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **why**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **justifies**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **denies**(ϕ)] [BtoA, **withdraws**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **resolve**(C Γ /C ϕ)] [BtoA, **withdraws**(ψ)] healthy

7.1.2.1.4. Challenge

Paired together with justification (section 7.1.2.5.), challenge forms the basis of the argumentation process. Challenging a statement differs from questioning it, for while in the latter case one is asking for some form of confirmation, in the former case one is asking for *good reasons* to stick to it.

Language: **why**(s): Why is it to be supposed that s? or
 How is it known that s?

Commitment Axioms

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{\text{why}}(\varphi)] C_a(\mathbf{\text{why}}(\varphi)) \wedge C_b\varphi$

After Party_A uttered $\mathbf{\text{why}}(\varphi)$ to Party_B, then given that P is a healthy state prior to the challenge, Party_A is committed to $\mathbf{\text{why}}(\varphi)$ and Party_B is committed to φ .

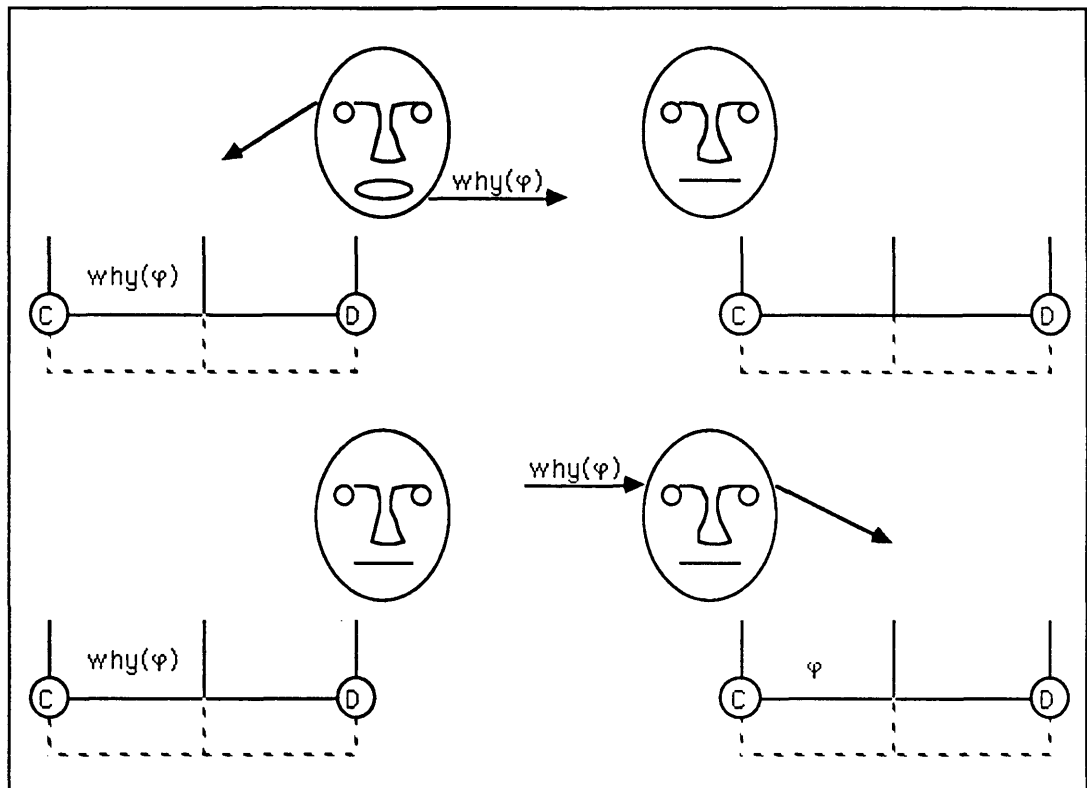


Figure 7.8 Talking Heads: Challenge I

A challenged Statement will be marked (as a challenged Statement) in the commitment store of the speaker. This is part of the mechanism to avoid circularity in answering other challenges ($\mathbf{\text{why}}(a)$; $\mathbf{\text{justifies}}(b)$; $\mathbf{\text{why}}(b)$; $\mathbf{\text{justifies}}(a)$). The challenged Statement is placed unmarked into the hearer's commitment store, to force him (her) to react to it.

A challenge is a demand for evidence. It is neither a demand for a confirmation nor for a denial like a question.

$$C_a\varphi \wedge C_b\varphi \rightarrow [AtoB, \mathbf{why}(\varphi)] C_a(\mathbf{why}(\varphi)) \wedge C_b\varphi$$

After Party_A uttered $\mathbf{why}(\varphi)$ to Party_B, then given that both parties are committed to φ prior to the challenge, A is committed to $\mathbf{why}(\varphi)$ - but not to φ any more - and Party_B remains committed to φ .

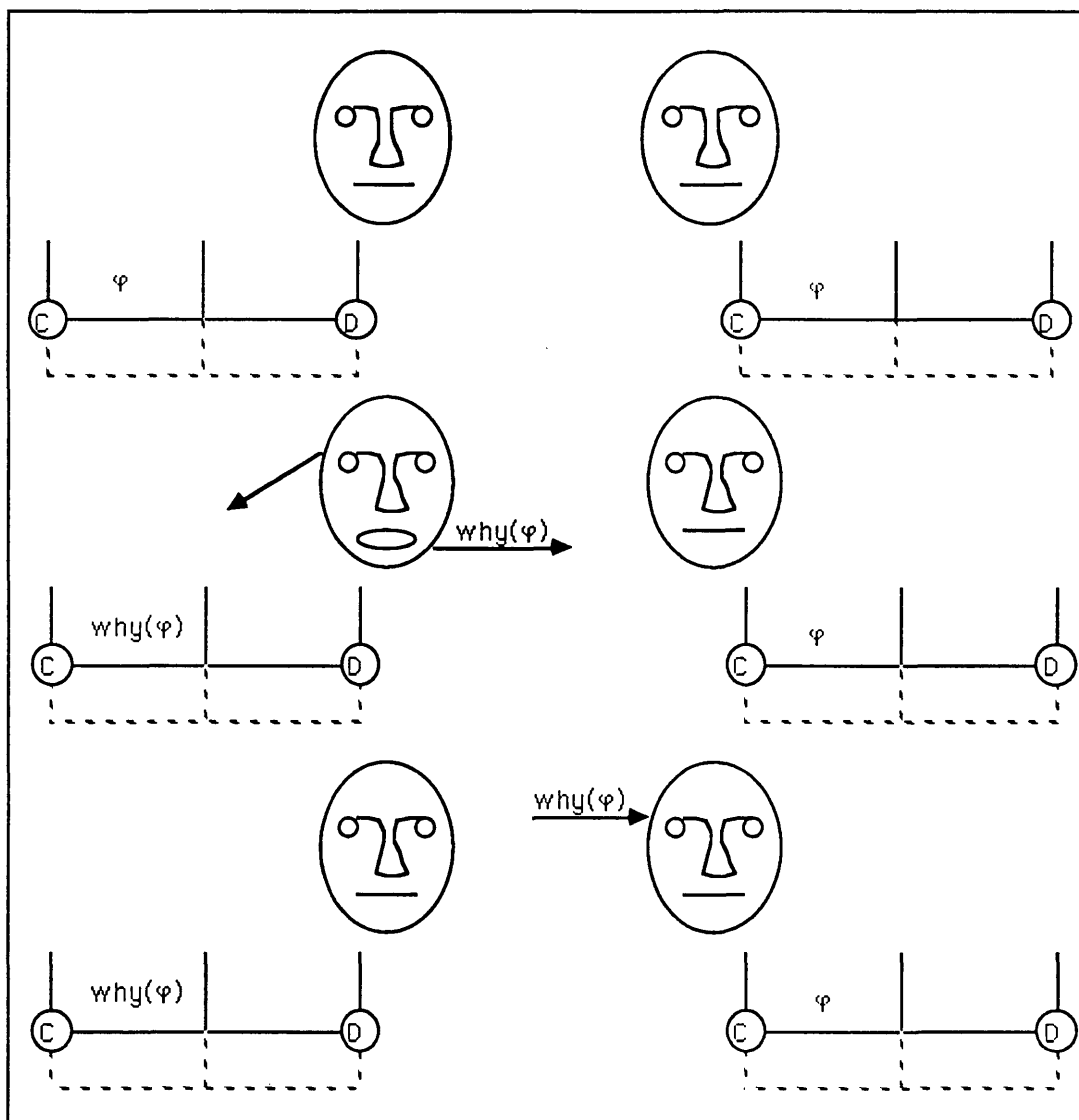


Figure 7.9 Talking Heads: Challenge II

A challenge forces the hearer to disclose the premises that led him to make that statement.

Legality Axioms

Starting with a challenge.

healthy to healthy

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{withdraws}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$

healthy to error

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{questions}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{asserts}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$

Ending with a challenge.

healthy to healthy

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{asserts}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{withdraws}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{healthy}$

healthy to error

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{questions}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{error}$

7.1.2.1.5. Justification

Given as an answer for a challenge, forms the basis of the argumentation process. It provides *good reasons* for the challenger to stick to the challenged statement.

Language: **justifies**(s): s is a justification for Challenge.

Commitment Axiom

$C_a(\mathbf{why}(\varphi)) \wedge C_b\varphi \rightarrow [BtoA, \mathbf{justifies}(\psi)]$

$C_a(\mathbf{why}(\varphi)) \wedge C_a(\psi \rightarrow \varphi) \wedge C_a\psi \wedge C_b\varphi \wedge C_b(\psi \rightarrow \varphi) \wedge C_b\psi$

After Party_B uttered **justifies**(ψ) to Party_A, then given that Party_A is committed to **why**(φ) and Party_B is committed to φ prior to the justification, Party_A is committed to **why**(φ), ($\psi \rightarrow \varphi$) and ψ , and Party_B is committed to φ , ($\psi \rightarrow \varphi$) and ψ after it.

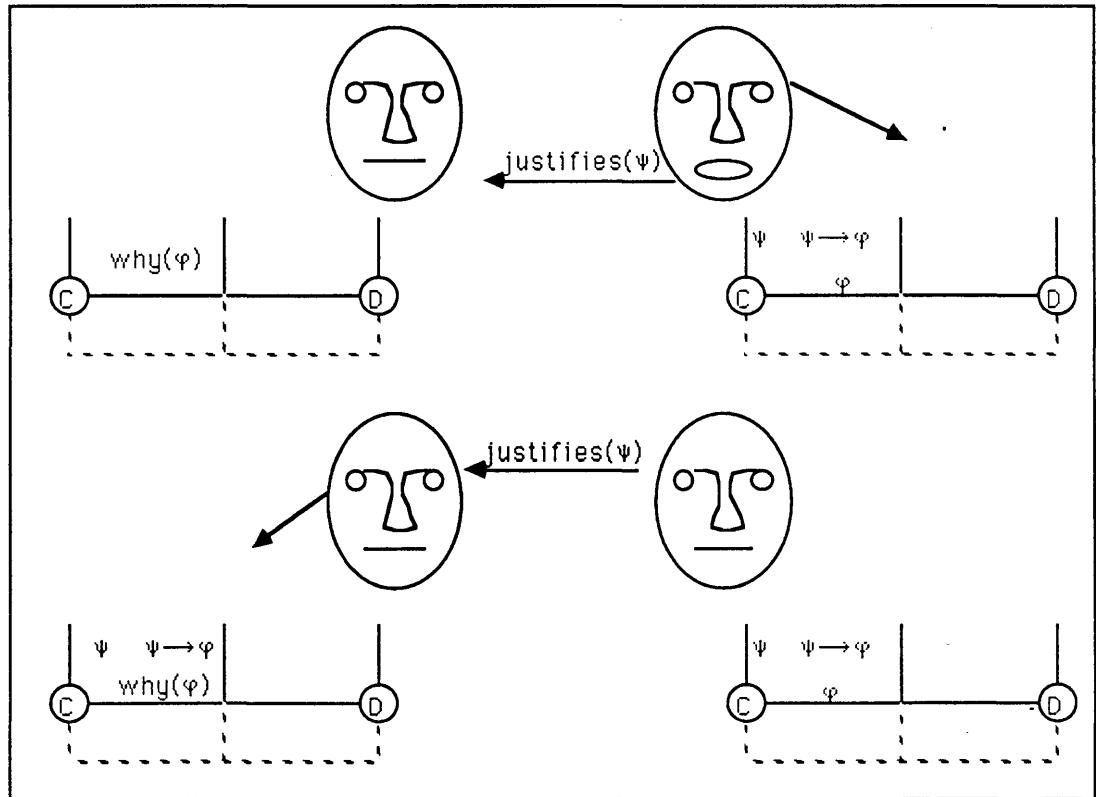


Figure 7.10 Talking Heads: Justification

A justification places the answer and the argumentation step $(\psi, (\psi \rightarrow \varphi))$ into both commitment stores. It provides the premises that support the challenged statement.

JustIMP is a variant form of the locution modifier Justification, specially designed for dealing with challenges of formulas containing one implication.

Commitment Axiom for the Justification for the Challenge of an Implication (justIMP)

$$C_a(\mathbf{why}(\gamma \rightarrow \varphi)) \wedge C_b(\gamma \rightarrow \varphi) \rightarrow [BtoA, \mathbf{justIMP}(\psi)]$$

$$C_a(\mathbf{why}(\gamma \rightarrow \varphi)) \wedge C_a(\psi \rightarrow \varphi) \wedge C_a\psi \wedge C_b(\gamma \rightarrow \varphi) \wedge C_b(\psi \rightarrow \varphi) \wedge C_b\psi$$

After Party_B uttered **justIMP**(ψ) to Party_A, then given that Party_A is committed to **why**($\gamma \rightarrow \varphi$) and Party_B is committed to $(\gamma \rightarrow \varphi)$ prior to the justification, Party_A is committed to **why**($\gamma \rightarrow \varphi$), $(\psi \rightarrow \varphi)$ and φ , and Party_B is committed to $(\gamma \rightarrow \varphi)$, $(\psi \rightarrow \varphi)$ and ψ after it.

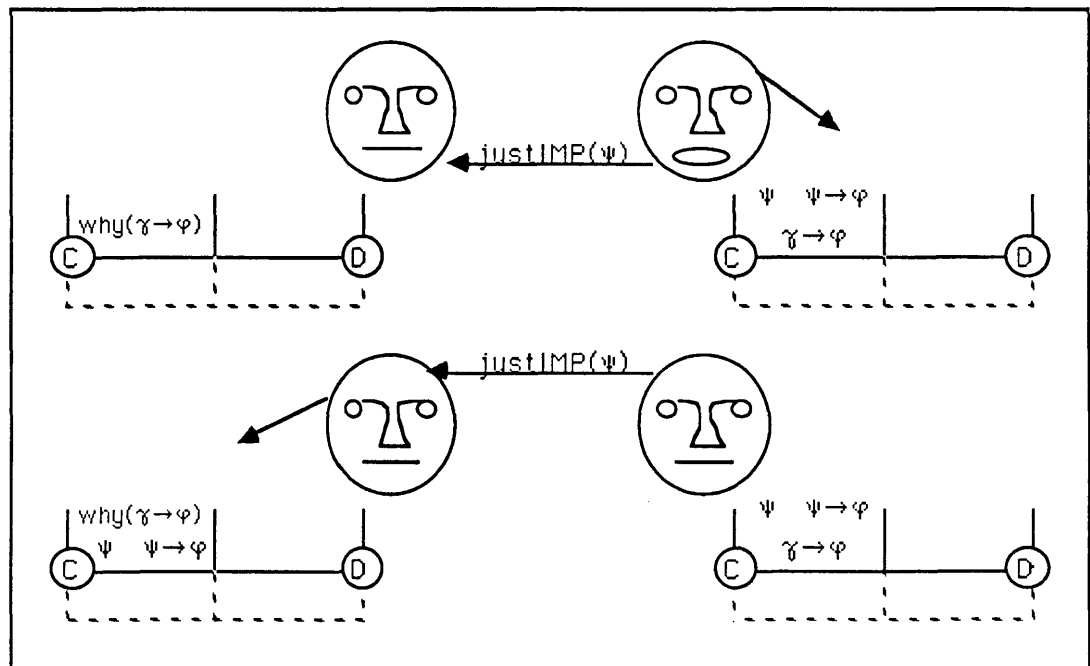


Figure 7.11 Talking Heads: JustIMP

JustIMP was designed in an *ad hoc* way. In the future we might resort to some specific reasoning strategies for justification to achieve the same result. The Legality Axioms are the same for Justification and for JustIMP.

Legality Axioms

Starting with a justification

healthy to healthy

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{withdraws}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{questions}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{asserts}(\psi)] \text{healthy}$

healthy to error

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$

Ending with a justification.

healthy to healthy

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{healthy}$

healthy to error

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{asserts}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{questions}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{withdraws}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$

7.1.2.1.6. Denial

This locution modifier can only be used after a question. It commits both the speaker and the hearer to the negation of the questioned statement.

Language: **denies(s)**: I deny that it is the case that s.

Commitment Axiom

healthy $\rightarrow$ [AtoB, **denies**(φ)] $C_a \neg \varphi \wedge C_b \neg \varphi$

After Party_A uttered **denies**(φ) to Party_B, then given that P is a healthy state prior to the denial, both parties are committed to $\neg \varphi$.

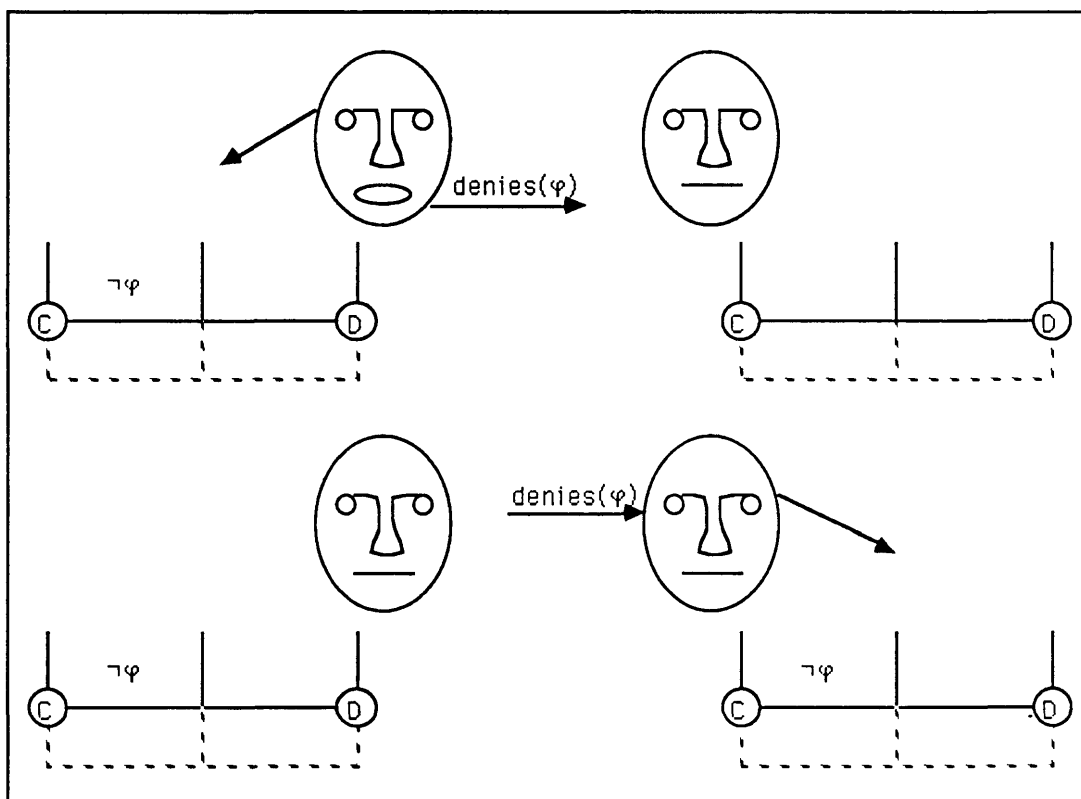


Figure 7.12 Talking Heads: Denial

In the commitment axiom above, we are treating the denial of a

statement as an assertion of the negation of that statement. Thus, a denial is stronger than a withdrawal.

Legality Axioms

Starting with a Denial.

healthy to healthy

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{asserts}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{withdraws}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{questions}(\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{why}(\psi)] \text{healthy}$

healthy to error

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{justifies}(\psi)] \text{error}$

Ending with a denial.

healthy to healthy

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{questions}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{healthy}$

healthy to error

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{asserts}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{withdraws}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\varphi)] [\text{BtoA}, \mathbf{denies}(\psi)] \text{error}$

7.1.2.1.7. Resolution Demand

It is used by the speaker to alert the hearer that his (the hearer's) commitment store is in a contradictory state. The hearer has to take some action to correct it.

The commitment calculus and CADReS are connected via this locution modifier. A party can only demand a resolution from the other party, if by the sole application of a commitment calculus rule, the latter's commitment store is proved to be contradictory. Otherwise the dialogue is not a healthy one any more. The proper uttering of a resolution demand does not affect the commitment stores.

Language: **resolve**(Set_of_Statements/Statements): Resolve this set of statements against this specific statement.

The commitment axioms for resolution demand have the general form:

$$C_b(\text{contradictory}) \rightarrow [A \text{ to } B, \text{resolve}(C\Gamma/C\phi)] C_b(\text{contradictory})$$

After Party_A uttered **resolve**(C Γ /C ϕ) - the set of commitments designated by Γ and the specific commitment ϕ being proved to be contradictory by the sole application of a commitment calculus rule - to Party_B, then given that Party_B has this form of contradiction in his commitment store prior to the resolution demand, both commitment stores remain the same after it.

Below we instantiate this commitment axiom using three potential contradictory commitment stores:

$C_b(\varphi \wedge \psi) \wedge C_b \neg \varphi \rightarrow [A \text{ to } B, \text{resolve}(C(\varphi \wedge \psi)/C \neg \varphi)] C_b(\varphi \wedge \psi) \wedge C_b \neg \varphi$

After Party_A uttered **resolve**($C(\varphi \wedge \psi)/C \neg \varphi$) to Party_B, then given that Party_B is committed to $(\varphi \wedge \psi)$ and $\neg \varphi$ prior to the resolution demand, both commitment stores remain the same after it.

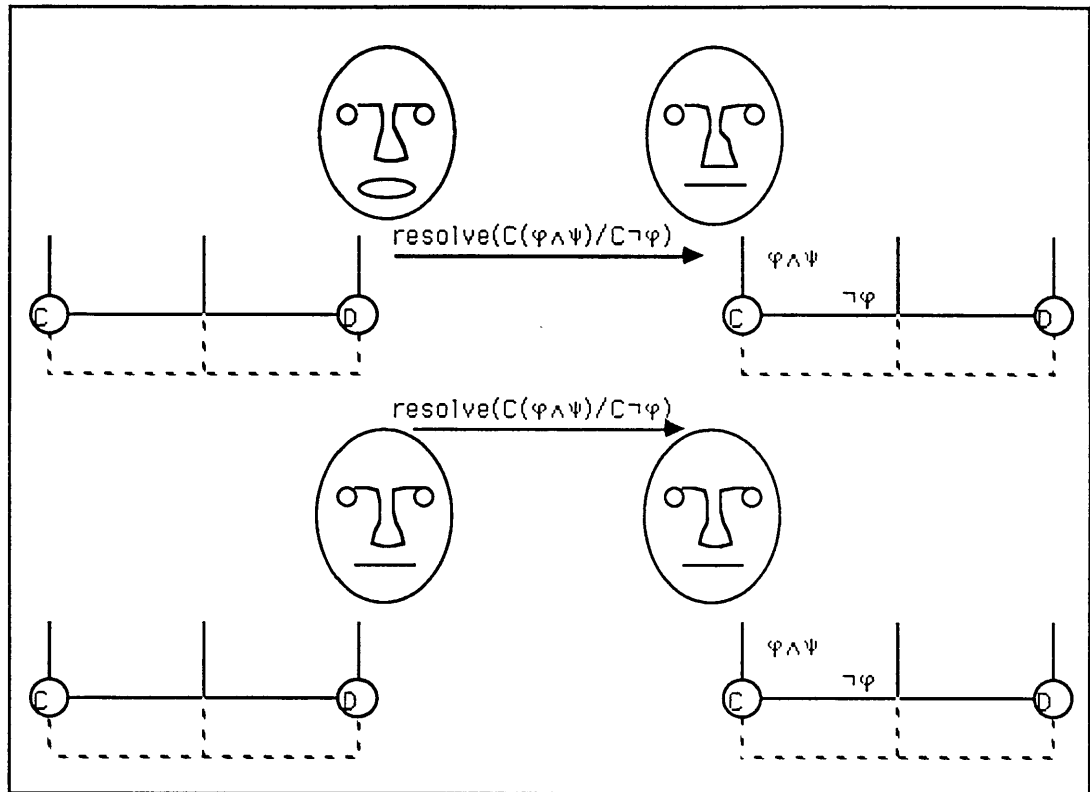
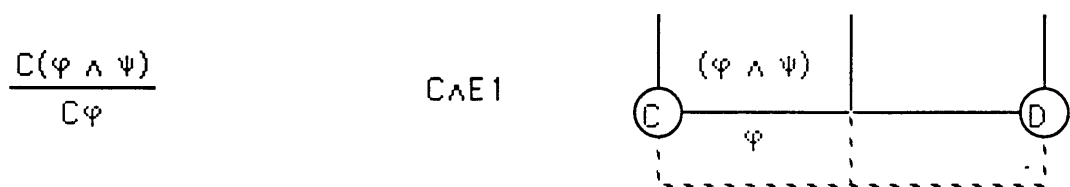


Figure 7.13 Talking Heads: Resolution Demand (C^{E1})

From rule C^{E1} below we see that Party_B's commitment store is in a contradictory state.



$$C(\varphi \rightarrow \psi) \wedge C\varphi \wedge C\neg\psi \rightarrow$$

$$[AtoB, \mathbf{resolve}(C(\varphi \rightarrow \psi), C\varphi/C\neg\psi)] C(\varphi \rightarrow \psi) \wedge C\varphi \wedge C\neg\psi$$

After Party_A uttered **resolve**($C(\varphi \rightarrow \psi), C\varphi/C\neg\psi$) to Party_B, then given that Party_B is committed to $(\varphi \rightarrow \psi)$, φ and $\neg\psi$ prior to the resolution demand, both commitment stores remain the same.

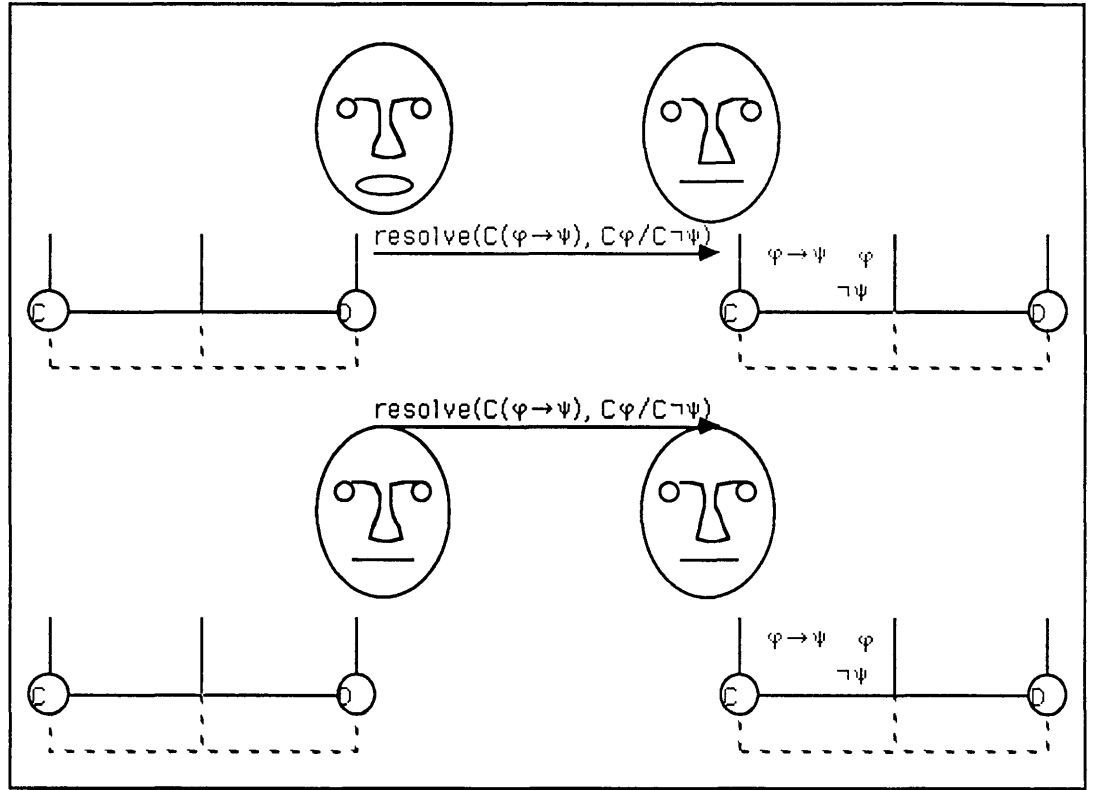
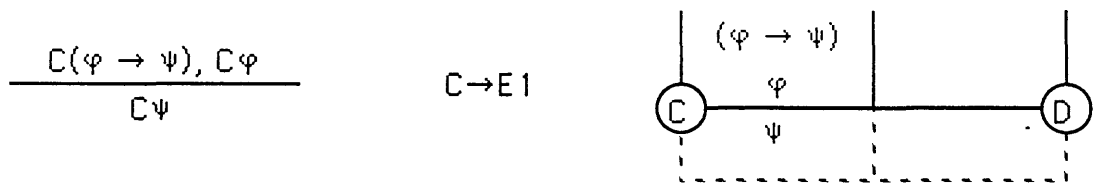


Figure 7.14 Talking Heads: Resolution Demand ($C \rightarrow E1$)

From rule $C \rightarrow E1$ below we see that Party_B's commitment store is in a contradictory state.



$D\phi \wedge D(\phi \wedge \psi) \rightarrow [A \text{ to } B, \text{resolve}(D\phi/D(\phi \wedge \psi))] \text{ error}$

After Party_A uttered $\text{resolve}(D\phi/D(\phi \wedge \psi))$ to Party_B, then given that Party_A is not committed to ϕ and $(\phi \wedge \psi)$ prior to the resolution demand, P' is an error state, i.e. the improper uttering of a resolution demand places 'error' in the speaker's C-commitment store. Party_B remains not committed to ϕ and $(\phi \wedge \psi)$.

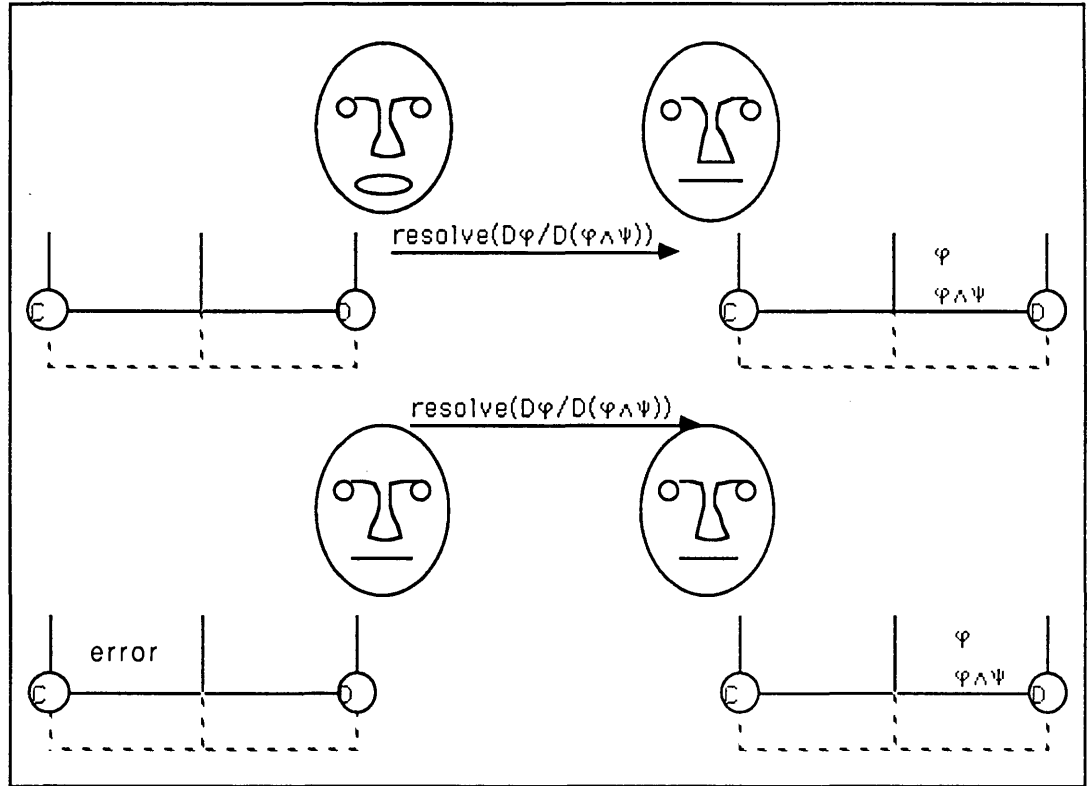
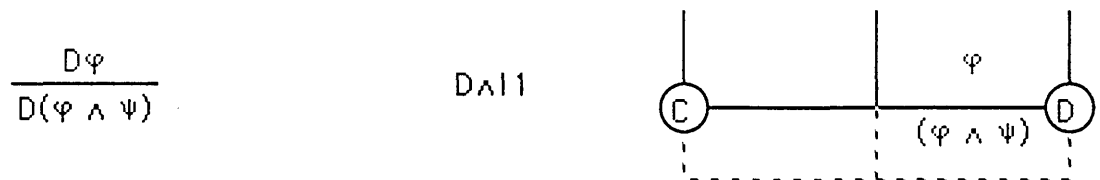


Figure 7.15 Talking Heads: Resolution Demand ($D\wedge I1$)

From rule $D\wedge I1$ below we cannot detect any contradiction in Party_B's commitment store.



At the current stage of this work, the party that is asking for the resolution demand, does not have to show which commitment calculus

rule he used to spot the contradiction. In the future we might make this necessary, for in a cooperative environment showing the means by which one detected a mistake is always helpful.

Finally concerning CADReS, being committed to something and not being committed to the same thing implies having a contradictory commitment store. Thus Party_B can demand a resolution from Party_A if $\{C_a\phi \wedge C_a\neg\phi\}$. However, if instead Party_A's commitment store's contents were $\{D_a\phi \wedge D_a\neg\phi\}$, then a resolution demand coming from Party_B would bring the dialogue to an error state. For example, if I'm committed to go to the cinema and I'm committed not to go to the cinema, then there is something wrong with me. On the other hand, if I'm not committed to go to the cinema and I'm not committed not to go to the cinema, apart from a strange fixation on movies, there is nothing wrong with me.

Legality Axioms

Starting with a resolution demand.

healthy to healthy

healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **asserts**(ψ)] healthy
 healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **withdraws**(ψ)] healthy

healthy to error

healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **resolve**($C\Gamma/C\psi$)] error
 healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **questions**(ψ)] error
 healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **why**(ψ)] error
 healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **denies**(ψ)] error
 healthy $\rightarrow$ [AtoB, **resolve**($C\Gamma/C\phi$)] [BtoA, **justifies**(ψ)] error

Ending with a resolution demand.

healthy to healthy

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{asserts}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{withdraws}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{why}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{justifies}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{denies}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{healthy}$

healthy to error

$\text{healthy} \rightarrow [\text{AtoB}, \mathbf{questions}(\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{error}$
 $\text{healthy} \rightarrow [\text{AtoB}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\varphi)] [\text{BtoA}, \mathbf{resolve}(\text{C}\Gamma/\text{C}\psi)] \text{error}$

7.2. Derivability ($\vdash$ CADReS)

The only rule necessary for defining the Commitment Action Dialogue Reasoning derivability relation - $\vdash_{\text{CADReS}}$ - is the transitivity rule shown below.

Transitivity rule:

$$\frac{P \rightarrow [\text{AtoB}, \mathbf{Loc}] P' \quad P' \rightarrow [\text{BtoA}, \mathbf{Loc}'] P''}{P \rightarrow [\text{AtoB}, \mathbf{Loc}] [\text{BtoA}, \mathbf{Loc}'] P''}$$

Given a set Γ of propositions of L_{CADReS} and $\varphi \in L_{\text{CADReS}}$ then,

$\Gamma \vdash_{\text{CADReS}} \varphi$ iff
 $\exists \varphi_1, \varphi_2, \dots, \varphi_n$ where
 $\varphi = \varphi_n$ and
 for each $i, i = 1$ to n ,
 $\varphi_i \in \Gamma$ or
 $\varphi_i \in$ logical axioms of CADReS or
 φ_i is the conclusion of the transitivity rule using premisses
 φ_j and φ_k for $j, k < i$.

Definition of Healthy Dialogue:

A dialogue is legal iff

$$\begin{aligned} & \vdash_{\text{CADReS}} P \rightarrow [\text{Party}_i \text{to} \text{Party}_j, \text{locution}]^n P \text{ or} \\ & \Gamma \vdash_{\text{CADReS}} P \rightarrow [\text{Party}_i \text{to} \text{Party}_j, \text{locution}]^n P \\ & \text{where } n \geq 1 \text{ and } j \neq i. \end{aligned}$$

7.3. Patterns of Cooperative Reasoning

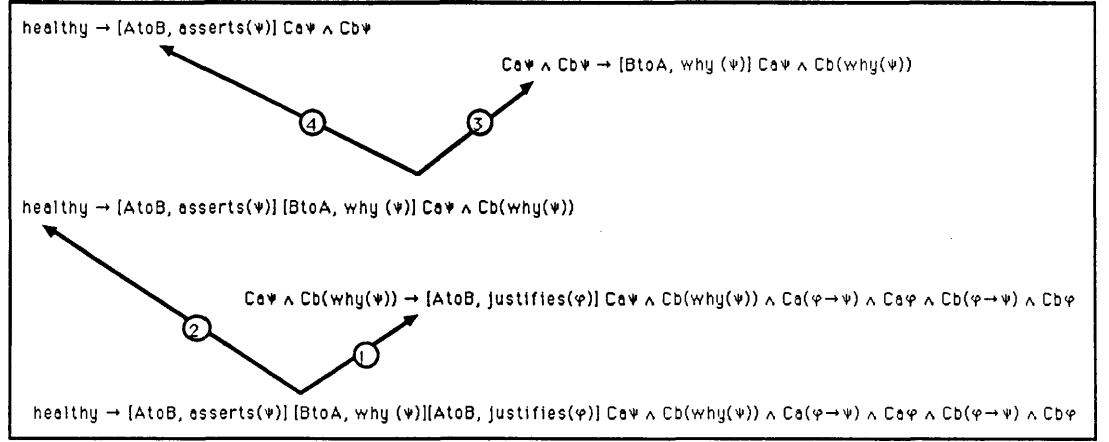
In this section we present two small patterns of cooperative reasoning. By cooperative reasoning we loosely mean the kind of reasoning that is common in the office and in the classroom for example. Although not particularly relevant at this stage of the work, an interesting *classification of cooperative illocutionary acts* provided by Hancher (1979) is going to be taken into consideration for future extensions.

Below we check if they are CADReS-derivable:

1) The dialogue presented below typifies a **justifying** conversation, where Party_A is challenged by Party_B to justify his (her) previous assertion.

$$\begin{aligned} \text{healthy} & \rightarrow [\text{AtoB}, \text{asserts}(\psi)] \\ & [\text{BtoA}, \text{why}(\psi)] \\ & [\text{AtoB}, \text{justifies}(\varphi)] \\ & C_a \psi \wedge C_b(\text{why}(\psi)) \wedge C_a(\varphi \rightarrow \psi) \wedge C_a \varphi \wedge C_b(\varphi \rightarrow \psi) \wedge C_b \varphi \end{aligned}$$

The figure below shows the derivation tree for this *dialogue*:



In all steps we check if the post-condition is well formed. Then, we check if the sequencing of the dialogue events is sound.

The post-condition $\{C_a\psi \wedge C_b(\mathbf{why}(\psi)) \wedge C_a(\varphi \rightarrow \psi) \wedge C_a\varphi \wedge C_b(\varphi \rightarrow \psi) \wedge C_b\varphi\}$ is well formed.

The sequencing of dialogue events $\{[BtoA, \mathbf{why}(\psi)] [AtoB, \mathbf{justifies}(\varphi)]\}$ is sound according to one of the legality axioms for Challenge.

We take the post-condition $\{C_a\psi \wedge C_b(\mathbf{why}(\psi)) \wedge C_a(\varphi \rightarrow \psi) \wedge C_a\varphi \wedge C_b(\varphi \rightarrow \psi) \wedge C_b\varphi\}$ together with the second dialogue event from the chosen pair $\{[AtoB, \mathbf{justifies}(\varphi)]\}$ and transform it to the pre-condition that makes the commitment axiom for that specific locution $\{\mathbf{justifies}\}$ correct. Thus we get $\{C_a\psi \wedge C_b(\mathbf{why}(\psi))\}$ as the pre-condition for (1).

The pre-condition for (1) is the post-condition for (2), and it is correct by construction (or, more appropriately, by destruction).

The sequencing of dialogue events $\{[AtoB, \mathbf{asserts}(\psi)] [BtoA, \mathbf{why}(\psi)]\}$ is sound according to one of the legality axioms for Assertion.

We take the post-condition $\{C_a\psi \wedge C_b(\mathbf{why}(\psi))\}$ together with the second dialogue event from the chosen pair $\{[BtoA, \mathbf{why}(\psi)]\}$ and transform it to the pre-condition that makes the commitment axiom for Challenge

correct. Thus we get $\{C_a\psi \wedge C_b\psi\}$ as the pre-condition for (3).

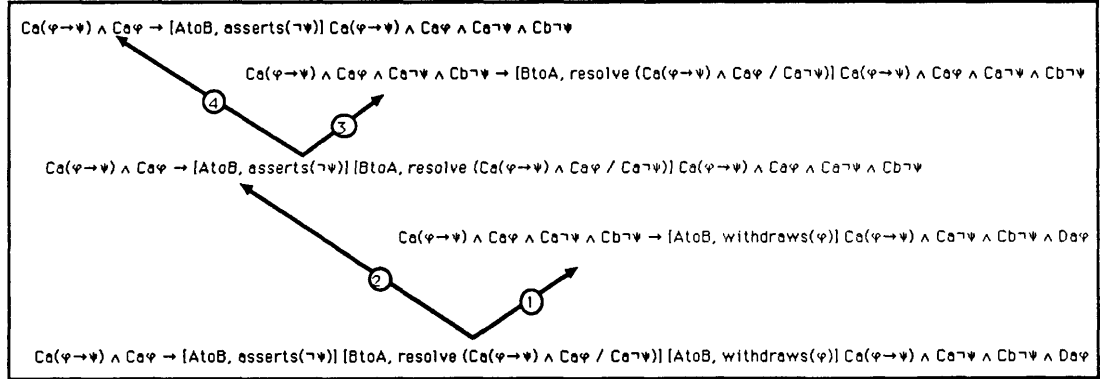
The pre-condition for (3) is the post-condition for (4).

Given that (4) is the first dialogue event, we only have to take its post-condition $\{C_a\psi \wedge C_b\psi\}$ together with the dialogue event $\{[AtoB, \mathbf{asserts}(\psi)]\}$ and transform it to the pre-condition that makes the commitment axiom for Assertion healthy. Thus we get $\{\text{healthy}\}$, which matches with our *dialogue* pre-condition. QED.

2) The dialogue presented below typifies a **resolving** conversation, where Party_A is urged by Party_B to resolve a contradiction in his (her) commitment store, that was created by his (her) previous assertion.

$$\begin{aligned}
 &C_a(\varphi \rightarrow \psi) \wedge C_a\varphi \rightarrow [AtoB, \mathbf{asserts}(\neg\psi)] \\
 &\quad [BtoA, \mathbf{resolve}(C_a(\varphi \rightarrow \psi) \wedge C_a\varphi / C_a\neg\psi)] \\
 &\quad [AtoB, \mathbf{withdraws}(\varphi)] \\
 &C_a(\varphi \rightarrow \psi) \wedge C_a\neg\psi \wedge C_b\neg\psi \wedge D_a\varphi
 \end{aligned}$$

The figure below shows the derivation tree for this *dialogue*:



In all we steps check if the post-condition is well formed. Then, we check if the sequencing of the dialogue events is sound.

The post-condition $\{C_a(\varphi \rightarrow \psi) \wedge C_a\neg\psi \wedge C_b\neg\psi \wedge D_a\varphi\}$ is well formed.

The sequencing of dialogue events $\{[BtoA, \mathbf{resolve}(C_a(\varphi \rightarrow \psi) \wedge C_a\varphi / C_a\neg\psi)] [AtoB, \mathbf{withdraws}(\varphi)]\}$ is sound according to one of the legality axioms for Resolution Demand.

We take the post-condition $\{C_a(\varphi \rightarrow \psi) \wedge C_a\neg\psi \wedge C_b\neg\psi \wedge D_a\varphi\}$ together with the second dialogue event from the chosen pair $\{[AtoB, \mathbf{withdraws}(\varphi)]\}$ and transform it to the pre-condition that makes the commitment axiom for that specific locution $\{\mathbf{withdraws}\}$ correct. Thus we get $\{C_a(\varphi \rightarrow \psi) \wedge C_a\varphi \wedge C_a\neg\psi \wedge C_b\neg\psi\}$ as the pre-condition for (1).

The pre-condition for (1) is the post-condition for (2), and it is correct by construction.

The sequencing of dialogue events $\{[AtoB, \mathbf{asserts}(\neg\psi)] [BtoA, \mathbf{resolve}(C_a(\varphi \rightarrow \psi) \wedge C_a\varphi / C_a\neg\psi)]\}$ is sound according to one of the legality axioms for Assertion.

We take the post-condition $\{C_a(\varphi \rightarrow \psi) \wedge C_a\varphi \wedge C_a\neg\psi \wedge C_b\neg\psi\}$ together with the second dialogue event from the chosen pair $\{[BtoA, \mathbf{resolve}(C_a(\varphi \rightarrow \psi) \wedge C_a\varphi / C_a\neg\psi)]\}$ and check if there is a commitment calculus rule that given $\{C_a(\varphi \rightarrow \psi) \wedge C_a\varphi\}$ as a premise, it concludes an implicit commitment that contradicts $\{C_a\neg\psi\}$. We find rule $C \rightarrow E1$. Then we transform it to the pre-condition that makes the commitment axiom for Resolution Demand correct. Thus we get $\{C_a(\varphi \rightarrow \psi) \wedge C_a\varphi \wedge C_a\neg\psi \wedge C_b\neg\psi\}$ as the pre-condition for (3).

The pre-condition for (3) is the post-condition for (4).

Given that (4) is the first dialogue event, we only have to take its post-condition $\{C_a(\varphi \rightarrow \psi) \wedge C_a\varphi \wedge C_a\neg\psi \wedge C_b\neg\psi\}$ together with the dialogue event $\{[AtoB, \mathbf{asserts}(\neg\psi)]\}$ and transform it to the pre-condition that makes the commitment axiom for Assertion correct. Thus we get $\{C_a(\varphi \rightarrow \psi) \wedge C_a\varphi\}$, which matches with our *dialogue* pre-condition. QED.

7.4. Summary

In the previous chapter we developed a Commitment Calculus, the first level of our two-tiered Framework for Dialogue Reasoning Systems.

In this chapter we developed a Commitment Action Dialogue Reasoning System, which constitutes the second level of the Dialogue System. It was designed in an axiomatic way using a modal [action] logic presentation which was chosen for its elegant way of dealing with actions. This presentation will also support a future extension from the current two-party system to a N-party one without any major changes.

For each locution modifier (Assertion, Question, Withdrawal, Challenge, Justification - and Justification for the Challenge of an Implication, Denial and Resolution Demand), commitment and legality axioms were presented.

Finally, we checked if the framework is capable of providing a representation scheme for two small dialogues, which reproduce patterns of reasoning that appear in cooperative working environments.

Chapter 8

Post Facto Rationalisation

In this chapter we revisit the automated travel ticketing system example developed in chapter 3 using our Framework for Dialogue Reasoning Systems.

We start from the resulting commitment stores of examples B and C in chapter 3. Some changes to these stores are made necessary, because after the development of the commitment calculus in chapter 6, we introduced the 'C' and 'D' notation for commitments. We drop the working areas because they are not necessary for this chapter's purpose.

According to Adler (1927) 'Rationalisation is a case of thinking in which reasons are adduced to support a conclusion or a belief, or an opinion accepted or held on grounds other than the reasons thereto adduced'.

A post facto rationalisation (using CADReS) amounts to the decomposition of the chain of reasoning into individual locutions that justifies the achievement of the state of affairs described by the (resulting) commitment stores. This whole task has to be done using the representation schemes provided by CADReS.

For each example we try to identify bits of this decomposed chain of reasoning, that are similar to the patterns of cooperative reasoning presented at the end of the previous chapter.

8.1. Example B of Chapter 3

Let us check if the following *dialogue* is CADReS-derivable:

$C_a(\text{child} \rightarrow \text{ticket}) \rightarrow$
 $[AtoB, \mathbf{why}(\text{child} \rightarrow \text{ticket})]$
 $[BtoA, \mathbf{justIMP}(\text{discount_fare})]$
 $[AtoB, \mathbf{why}(\text{discount_fare})]$
 $[BtoA, \mathbf{justifies}(\text{entitled_discount})]$
 $[AtoB, \mathbf{why}(\text{entitled_discount})]$
 $[BtoA, \mathbf{justifies}(\text{id_card})]$
 $[AtoB, \mathbf{why}(\text{id_card})]$
 $[BtoA, \mathbf{justifies}(\text{child})]$
 $C_a(\mathbf{why}(\text{child} \rightarrow \text{ticket})) \wedge C_a(\text{discount_fare} \rightarrow \text{ticket}) \wedge$
 $C_a(\mathbf{why}(\text{discount_fare})) \wedge C_a(\text{entitled_discount} \rightarrow \text{discount_fare})$
 $\wedge C_a(\mathbf{why}(\text{entitled_discount})) \wedge C_a(\text{id_card} \rightarrow \text{entitled_discount})$
 $\wedge C_a(\mathbf{why}(\text{id_card})) \wedge C_a(\text{child}) \wedge C_a(\text{child} \rightarrow \text{id_card});$
 $C_b(\text{child} \rightarrow \text{ticket}) \wedge C_b(\text{discount_fare}) \wedge$
 $C_b(\text{discount_fare} \rightarrow \text{ticket}) \wedge C_b(\text{entitled_discount}) \wedge$
 $C_b(\text{entitled_discount} \rightarrow \text{discount_fare}) \wedge C_b(\text{id_card}) \wedge$
 $C_b(\text{id_card} \rightarrow \text{entitled_discount}) \wedge C_b(\text{child}) \wedge$
 $C_b(\text{child} \rightarrow \text{id_card}).$

Below we present the derivation tree for this *dialogue*:

In all steps we check if the post-condition is well formed. Then, we check if the sequencing of the dialogue events is sound.

The post-condition - the resulting commitment stores - is well formed.

The sequencing of dialogue events $\{[AtoB, \mathbf{why}(\text{id_card})] [BtoA, \mathbf{justifies}(\text{child})]\}$ is sound according to one of the legality axioms for Challenge.

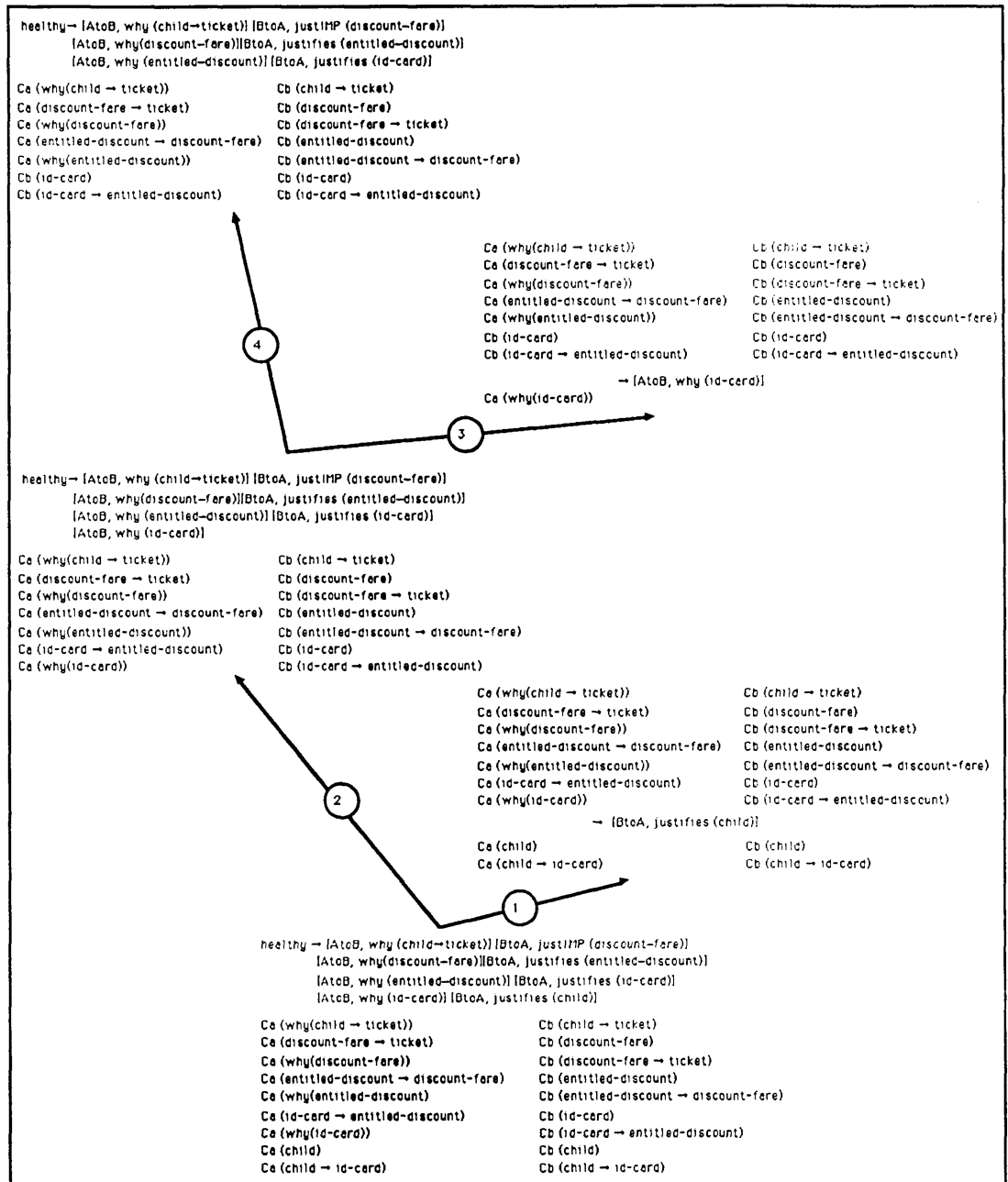


Fig 8.1 Example B Derivation Tree (1 of 4)

We take the post-condition together with the second dialogue event from the chosen pair $\{[BtoA, justifies(child)]\}$ and transform it to the pre-condition that makes the commitment axiom for that specific locution (**justifies**) correct. Thus we get the commitment stores below as the pre-conditions for (1).

$$\begin{aligned}
& C_a(\mathbf{why}(\text{child} \rightarrow \text{ticket})) \wedge C_a(\text{discount_fare} \rightarrow \text{ticket}) \wedge \\
& C_a(\mathbf{why}(\text{discount_fare})) \wedge C_a(\text{entitled_discount} \rightarrow \text{discount_fare}) \\
& \wedge C_a(\mathbf{why}(\text{entitled_discount})) \wedge C_a(\text{id_card} \rightarrow \text{entitled_discount}) \\
& \wedge C_a(\mathbf{why}(\text{id_card})); \\
& C_b(\text{child} \rightarrow \text{ticket}) \wedge C_b(\text{discount_fare}) \wedge \\
& C_b(\text{discount_fare} \rightarrow \text{ticket}) \wedge C_b(\text{entitled_discount}) \wedge \\
& C_b(\text{entitled_discount} \rightarrow \text{discount_fare}) \wedge C_b(\text{id_card}) \wedge \\
& C_b(\text{id_card} \rightarrow \text{entitled_discount}).
\end{aligned}$$

The pre-condition for (1) is the post-condition for (2), and it is correct by construction.

The proof goes on in the same fashion.

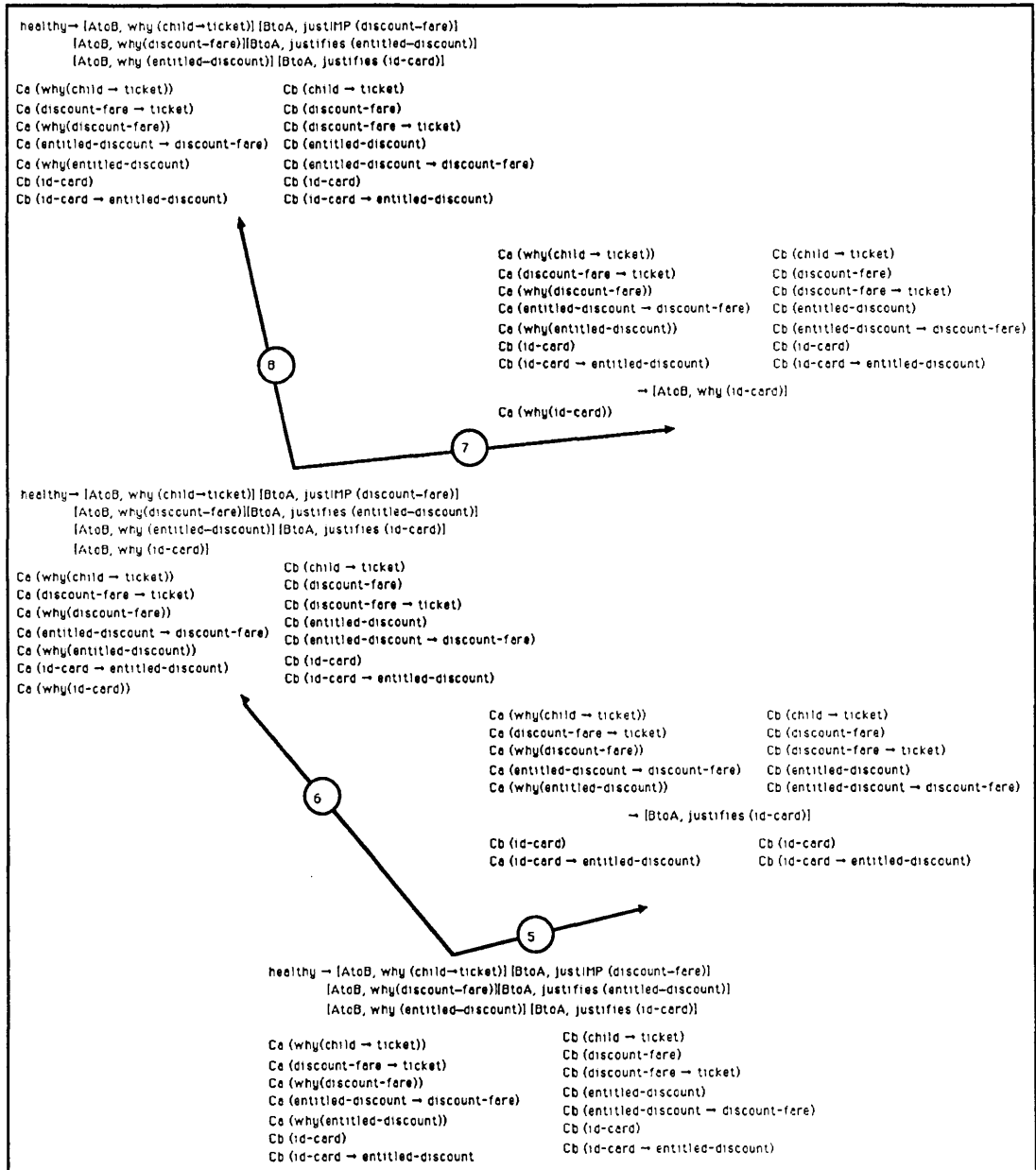


Fig 8.2 Example B Derivation Tree (2 of 4)

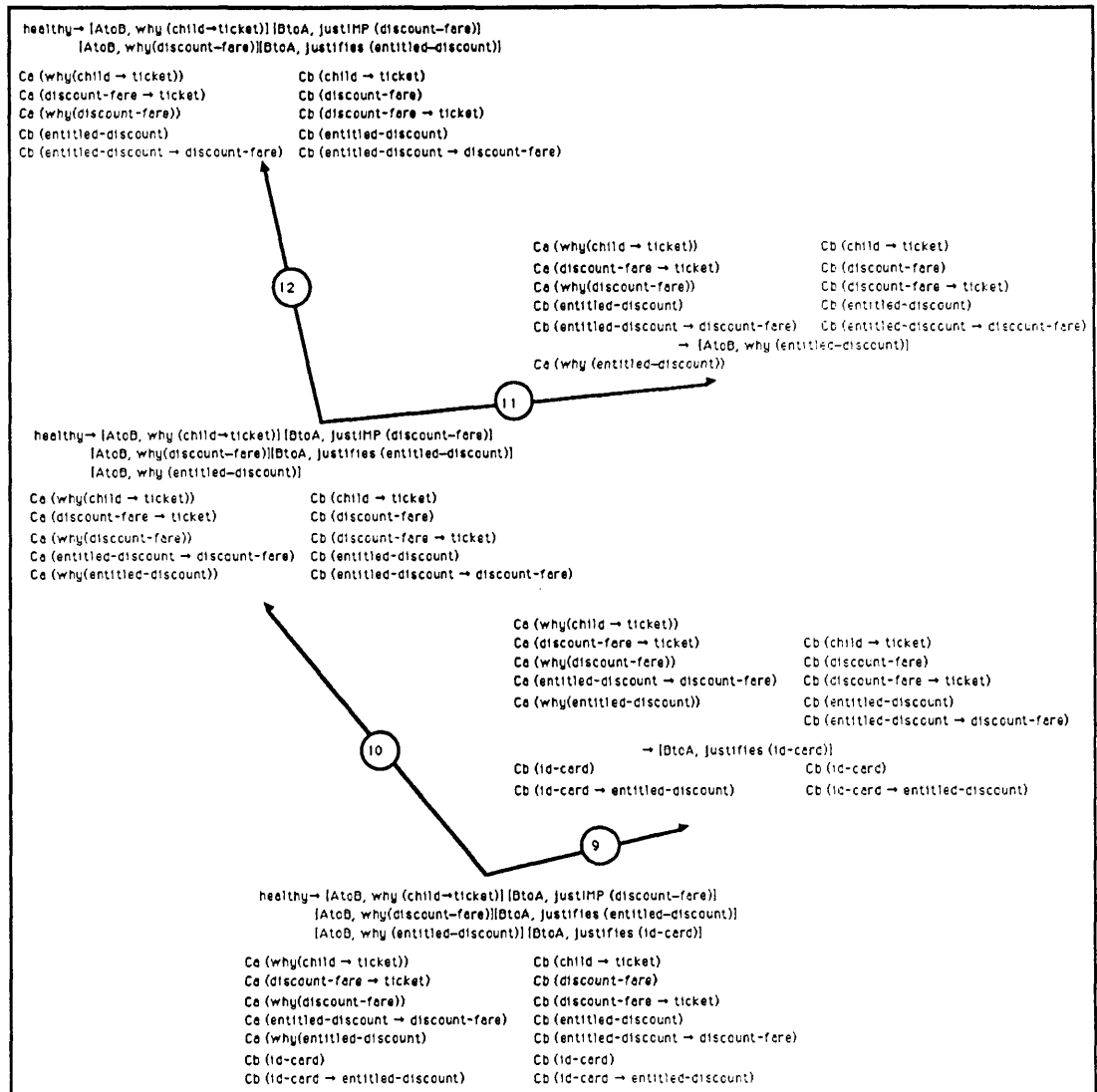


Fig 8.3 Example B Derivation Tree (3 of 4)

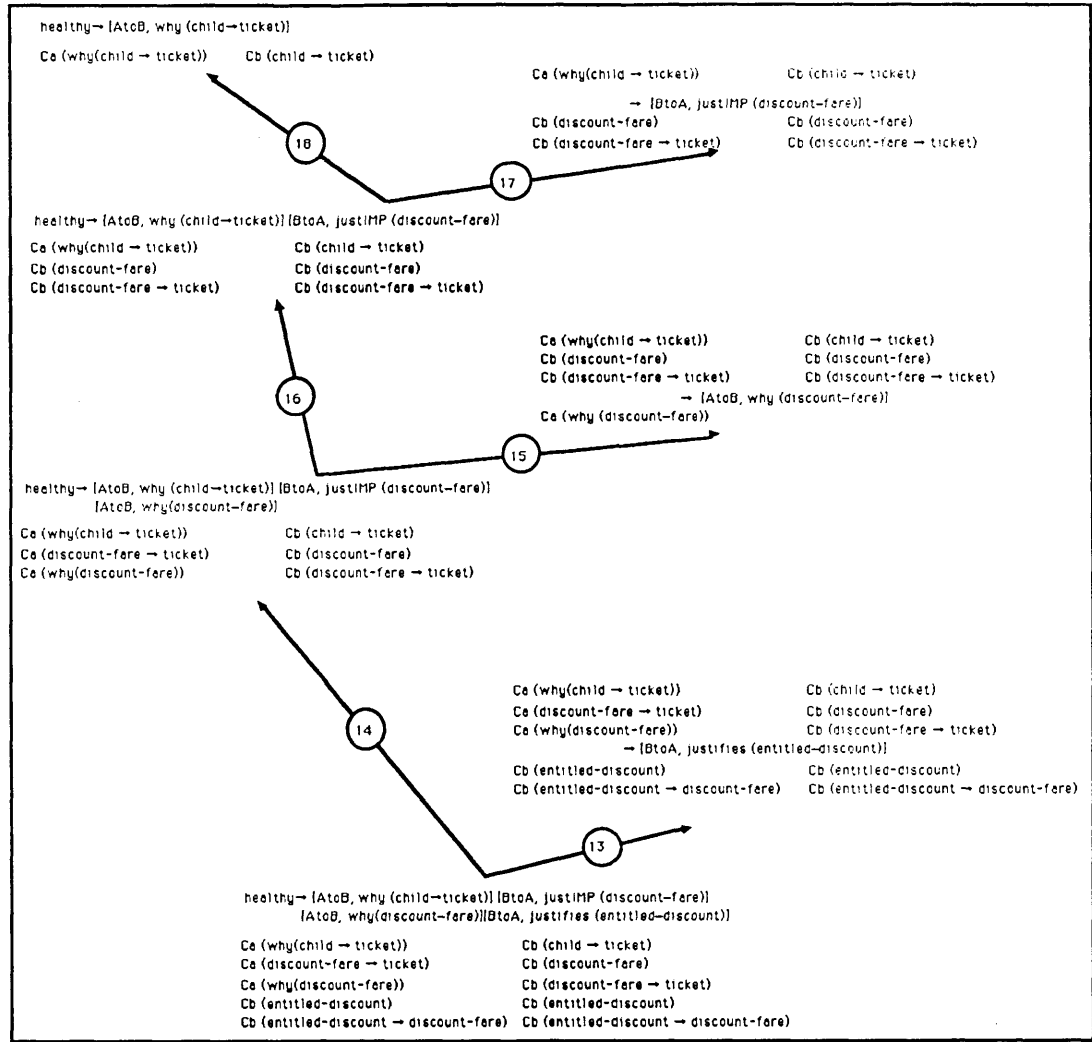


Fig 8.4 Example B Derivation Tree (4 of 4)

We rejoin the proof at step (17).

The post-condition $\{ \text{Ca}(\text{discount_fare}) \wedge \text{Ca}(\text{discount_fare} \rightarrow \text{ticket}) \wedge \text{Cb}(\text{discount_fare}) \wedge \text{Cb}(\text{discount_fare} \rightarrow \text{ticket}) \}$ is well formed.

The sequencing of dialogue events $\{ [\text{AtoB}, \text{why}(\text{child} \rightarrow \text{ticket})] [\text{BtoA}, \text{justIMP}(\text{discount_fare})] \}$ is sound according to the legality axiom especially designed for dealing with challenges of formulas containing one implication.

We take the post-condition together with the second dialogue event from

the chosen pair $\{[BtoA, \mathbf{justIMP}(\text{discount_fare})]\}$ and transform it to the pre-condition that makes the commitment axiom for that specific location $\{\mathbf{justIMP}\}$ correct. In this special case we also have to have a look at the first dialogue event from the chosen pair $\{[AtoB, \mathbf{why}(\text{child} \rightarrow \text{ticket})]\}$, to retrieve the premise of the challenged conditional $\{\text{child}\}$. Thus we get $\{Ca(\mathbf{why}(\text{child} \rightarrow \text{ticket})) \wedge Cb(\text{child} \rightarrow \text{ticket})\}$ as the pre-condition for (17).

The pre-condition for (17) is the post-condition for (18), and it is correct by construction.

Given that (18) is the first dialogue event, we only have to take its post-condition $\{Ca(\mathbf{why}(\text{child} \rightarrow \text{ticket})) \wedge Cb(\text{child} \rightarrow \text{ticket})\}$ together with the dialogue event $\{[AtoB, \mathbf{why}(\text{child} \rightarrow \text{ticket})]\}$ and transform it to the pre-condition that makes the commitment axiom for Challenge correct. Thus we get *healthy*, which matches with our *dialogue* pre-condition. QED.

The dialogue above is CADReS derivable as we wanted to prove. It consists of sequences of challenges-justifications, which are similar to the pattern of cooperative reasoning called *justifying* presented in section 7.3. The next example is a *richer* one in the sense that it not only contains this pattern (challenge-justification), but also some questioning-answering, and the other pattern introduced in section 7.3. (*resolving*).

8.2. Example C of Chapter 3

Let us check if the following *dialogue* is CADReS-derivable:

healthy $\rightarrow$

[BtoA, **why**(oap $\rightarrow$ entitled_discount)]
 [AtoB, **justifies**(id_card)]
 [BtoA, **why**(id_card)]
 [AtoB, **withdraws**(id_card)]
 [BtoA, **questions**(oap $\rightarrow$ id_card)]
 [AtoB, **asserts**(oap $\rightarrow$ id_card)]
 [BtoA, **questions**(oap)]
 [AtoB, **asserts**(oap)]
 [BtoA, **questions**(id_card)]
 [AtoB, **denies**(id_card)]
 [BtoA, **resolve**(C_aoap, C_a(oap $\rightarrow$ id_card)/ C_a $\neg$ id_card)]
 [AtoB, **withdraws**($\neg$ id_card)]
 [BtoA, **withdraws**($\neg$ id_card)]
 C_a(oap $\rightarrow$ entitled_discount) $\wedge$ C_a(id_card $\rightarrow$ entitled_discount) $\wedge$
 D_a(id_card) $\wedge$ C_a(oap $\rightarrow$ id_card) $\wedge$ C_a(oap) $\wedge$ D_a($\neg$ id_card);
 C_b(**why**(oap $\rightarrow$ entitled_discount)) $\wedge$
 C_b(id_card $\rightarrow$ entitled_discount) $\wedge$ C_b(**why**(id_card) $\wedge$
 C_b(oap $\rightarrow$ id_card) $\wedge$ C_b(oap) $\wedge$ D_b($\neg$ id_card).

Below we present the derivation tree for this *dialogue*:

In all steps we check if the post-condition is well formed. Then, we check if the sequencing of the dialogue events is sound.

The post-condition - the resulting commitment stores - is well formed.

The sequencing of dialogue events {[AtoB, **withdraws**($\neg$ id_card)] [BtoA, **withdraws**($\neg$ id_card)]} is sound according to one of the legality axioms for Challenge.

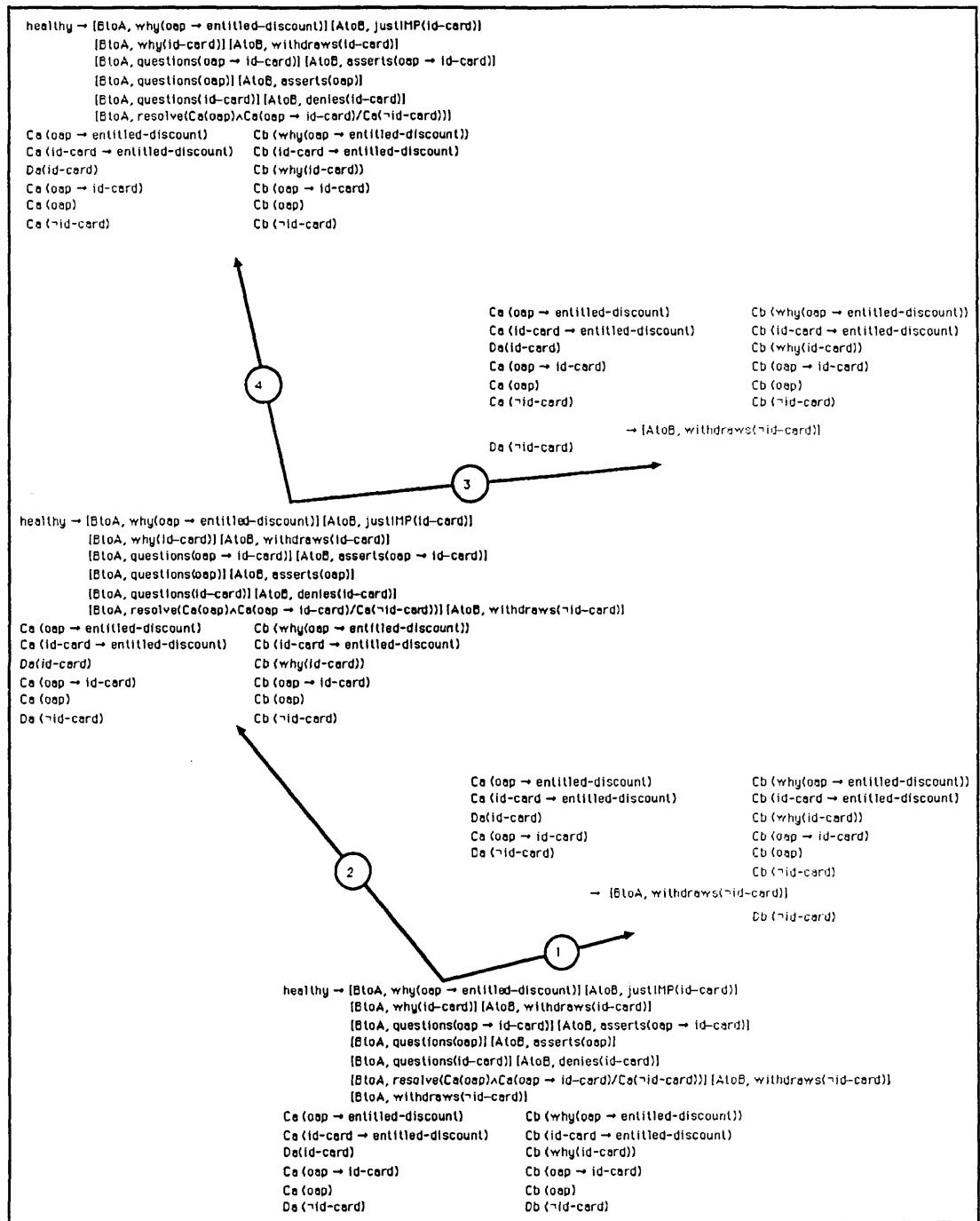


Fig 8.5 Example C Derivation Tree (1 of 4)

We take the post-condition together with the second dialogue event from the chosen pair {[BtoA, **withdraws**($\neg$ id_card)]} and transform it to the pre-condition that makes the commitment axiom for that specific locution {**withdraws**} correct. Thus we get the commitment stores below

as the pre-conditions for (1).

$$\begin{aligned}
& C_a(oap \rightarrow \text{entitled_discount})) \wedge C_a(id_card \rightarrow \text{entitled_discount}) \wedge \\
& D_a(id_card) \wedge C_a(oap \rightarrow id_card) \wedge C_a(oap) \wedge D_a(\neg id_card); \\
& C_b(\mathbf{why}(oap \rightarrow \text{entitled_discount})) \wedge \\
& C_b(id_card \rightarrow \text{entitled_discount}) \wedge C_b(\mathbf{why}(id_card) \wedge \\
& C_b(oap \rightarrow id_card) \wedge C_b(oap) \wedge C_b(\neg id_card)).
\end{aligned}$$

The pre-condition for (1) is the post-condition for (2), and it is correct by construction.

The sequencing of dialogue events $\{[BtoA, \mathbf{resolve}(oap, oap \rightarrow id_card / \neg id_card)][AtoB, \mathbf{withdraws}(\neg id_card)]\}$ is sound according to one of the legality axioms for Resolution Demand.

We take the post-condition

$$\begin{aligned}
& \{C_a(oap \rightarrow \text{entitled_discount})) \wedge C_a(id_card \rightarrow \text{entitled_discount}) \\
& \wedge D_a(id_card) \wedge C_a(oap \rightarrow id_card) \wedge C_a(oap) \wedge D_a(\neg id_card); \\
& C_b(\mathbf{why}(oap \rightarrow \text{entitled_discount})) \wedge \\
& C_b(id_card \rightarrow \text{entitled_discount}) \wedge C_b(\mathbf{why}(id_card) \wedge \\
& C_b(oap \rightarrow id_card) \wedge C_b(oap) \wedge C_b(\neg id_card)\}
\end{aligned}$$

together with the second dialogue event from the chosen pair $\{[AtoB, \mathbf{withdraws}(\neg id_card)]\}$ and transform it to the pre-condition that makes the commitment axiom for that specific locution $\{\mathbf{withdraws}\}$ correct. Thus we get the commitment stores below as the pre-conditions for (3).

The pre-condition for (3) is the post-condition for (4).

The sequencing of dialogue events $\{[AtoB, \mathbf{denies}(id_card)][BtoA, \mathbf{resolve}(oap, oap \rightarrow id_card / \neg id_card)]\}$ is sound according to one of the legality axioms for Denial.

We take the post-condition

$$\begin{aligned}
& \{C_a(oap \rightarrow \text{entitled_discount})\} \wedge C_a(\text{id_card} \rightarrow \text{entitled_discount}) \\
& \wedge D_a(\text{id_card}) \wedge C_a(oap \rightarrow \text{id_card}) \wedge C_a(oap) \wedge D_a(\neg \text{id_card}); \\
& C_b(\mathbf{why}(oap \rightarrow \text{entitled_discount})) \wedge \\
& C_b(\text{id_card} \rightarrow \text{entitled_discount}) \wedge C_b(\mathbf{why}(\text{id_card})) \wedge \\
& C_b(oap \rightarrow \text{id_card}) \wedge C_b(oap) \wedge C_b(\neg \text{id_card})\}
\end{aligned}$$

together with the second dialogue event from the chosen pair $\{[B \text{ to } A, \mathbf{resolve}(oap, oap \rightarrow \text{id_card} / \neg \text{id_card})]\}$ and check if there is a commitment calculus rule that given $\{C_a(oap \rightarrow \text{id_card}) \wedge C_a(oap)\}$ as a premise, it concludes an implicit commitment that contradicts $\{C_a(\neg \text{id_card})\}$. We find rule $C \rightarrow E1$. Then we transform it to the pre-condition that makes the commitment axiom for Resolution Demand correct. Thus we get the same stores as the pre-condition for (5). A resolution demand does not affect the commitment stores.

The proof goes on in the same fashion.

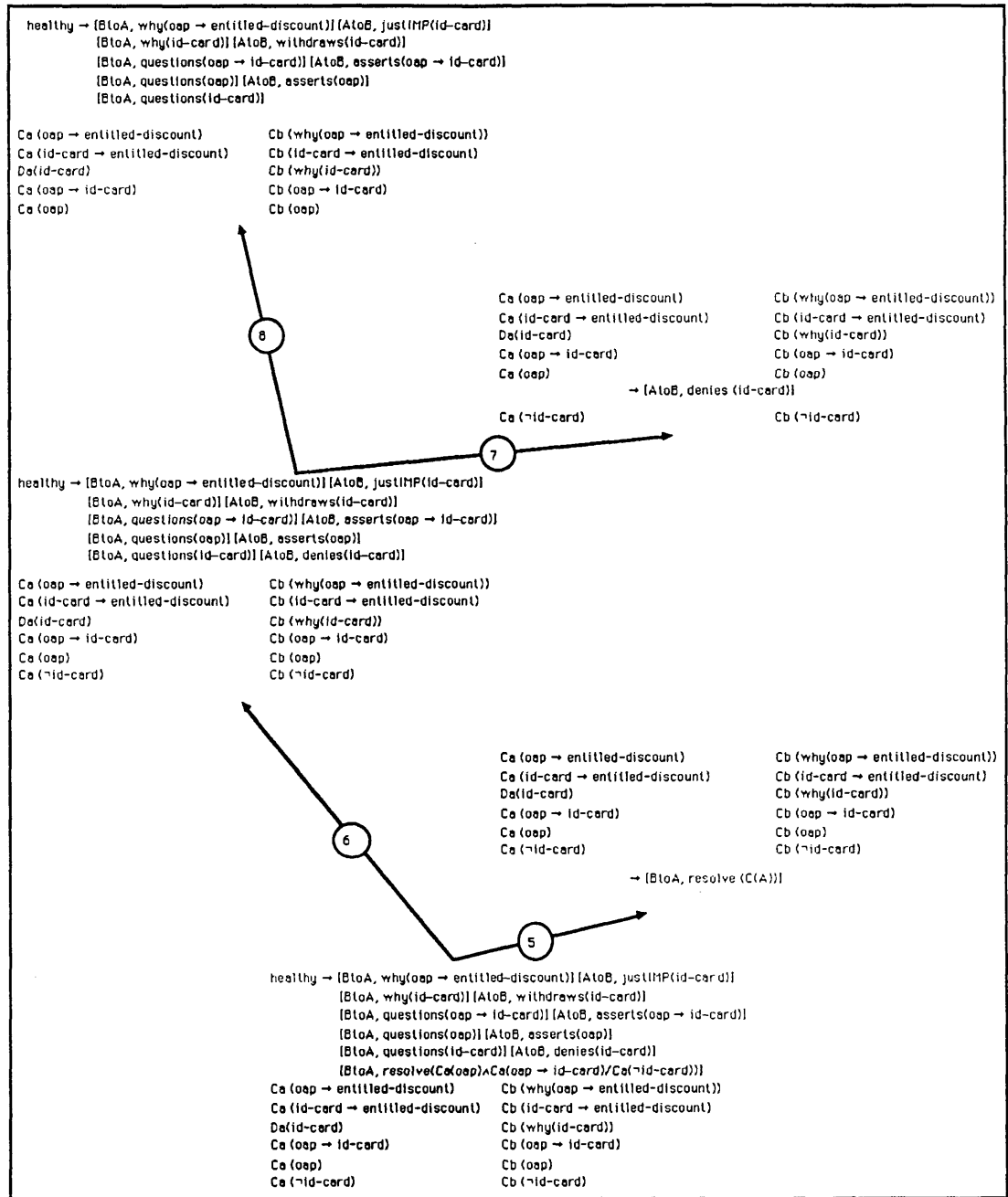


Fig 8.6 Example C Derivation Tree (2 of 4)

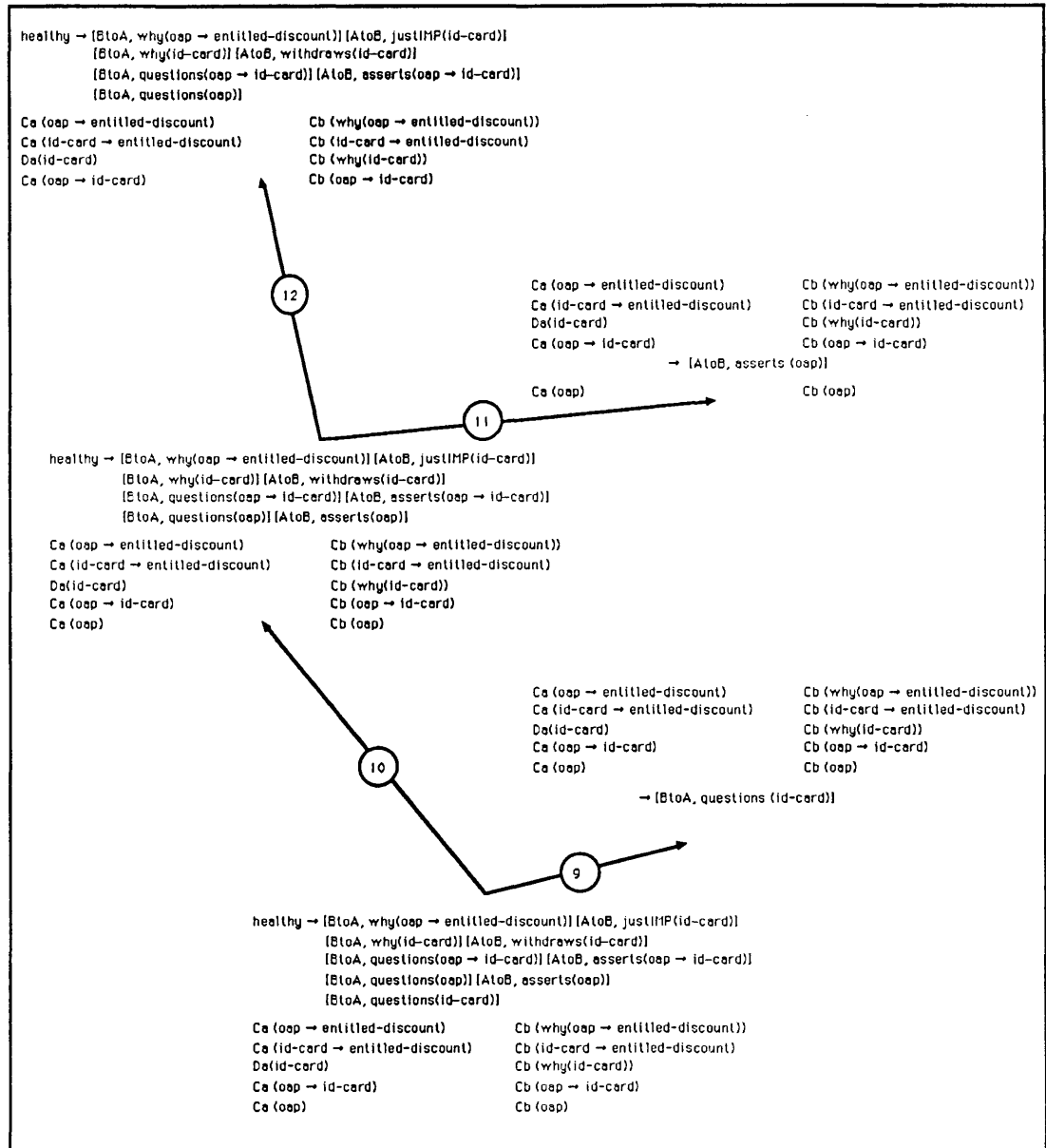


Fig 8.7 Example C Derivation Tree (3 of 4)

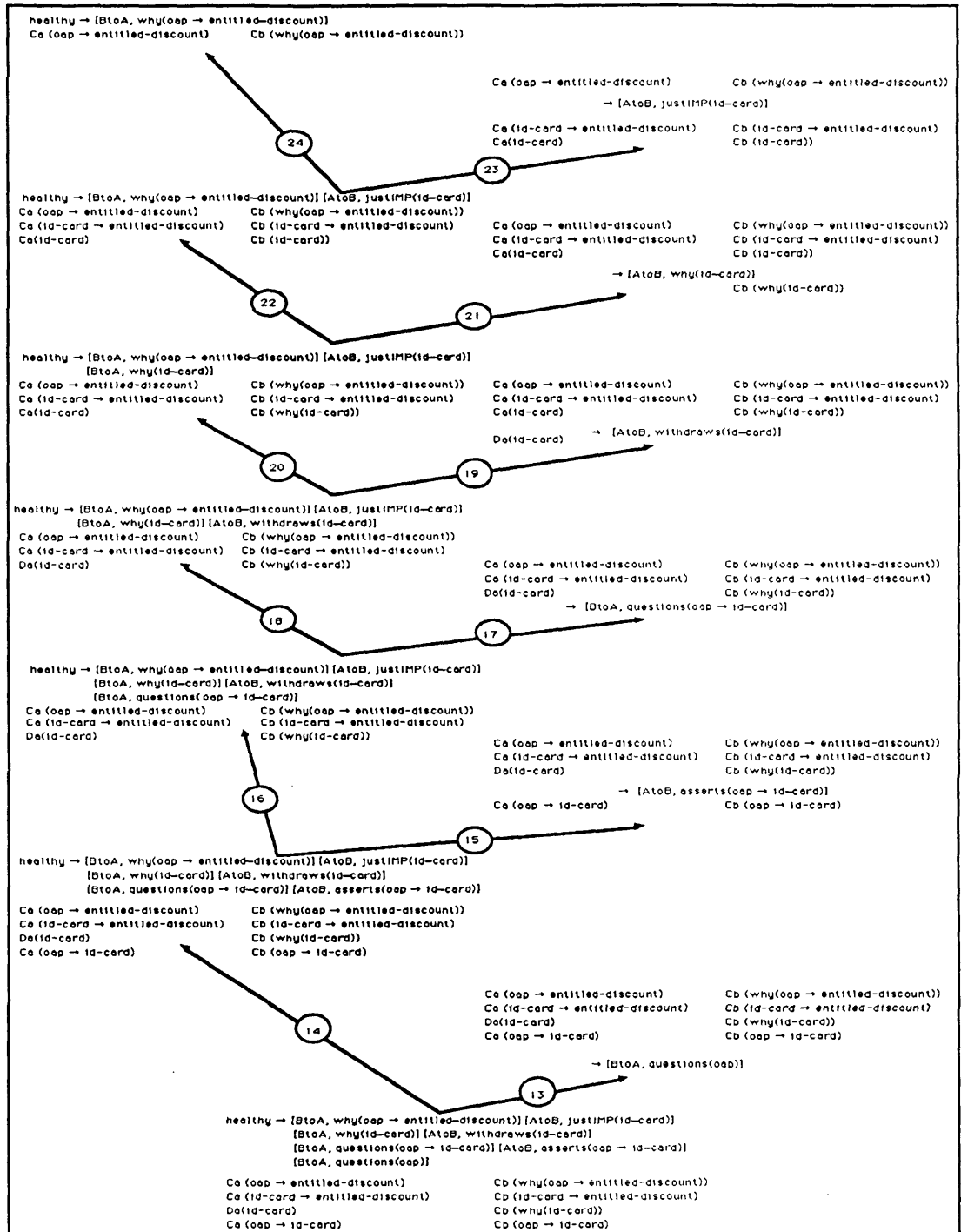


Fig 8.8 Example C Derivation Tree (4 of 4)

We rejoin the proof at step (23).

The post-condition $\{Ca(id_card \rightarrow entitled_discount) \wedge Ca(id_card) \wedge$

$Cb(id_card \rightarrow entitled_discount) \wedge Cb(id_card)$ is well formed.

The sequencing of dialogue events $\{[BtoA, \mathbf{why}(oap \rightarrow entitled_discount)] [AtoB, \mathbf{justIMP}(id_card)]\}$ is sound according to one of the legality axioms for Justification.

We take the post-condition together with the second dialogue event from the chosen pair $\{[AtoB, \mathbf{justIMP}(id_card)]\}$ and transform it to the pre-condition that makes the commitment axiom for that specific locution (**justIMP**) correct. In this special case we also have to have a look at the first dialogue event from the chosen pair $\{[AtoB, \mathbf{why}(oap \rightarrow entitled_discount)]\}$, to retrieve the premise of the challenged conditional {child}. Thus we get $\{Ca(\mathbf{why}(id_card \rightarrow entitled_discount)) \wedge Cb(id_card \rightarrow entitled_discount)\}$ as the pre-condition for (23).

The pre-condition for (23) is the post-condition for (24), and it is correct by construction.

Given that (24) is the first dialogue event, we only have to take its post-condition $\{Ca(\mathbf{why}(oap \rightarrow entitled_discount)) \wedge Cb(oap \rightarrow entitled_discount)\}$ together with the dialogue event $\{[BtoA, \mathbf{why}(oap \rightarrow entitled_discount)]\}$ and transform it to the pre-condition that makes the commitment axiom for Challenge correct. Thus we get *healthy*, which matches with our *dialogue* pre-condition. QED.

The dialogue above is CADReS derivable as we wanted to prove. It consists of sequences of challenges-justifications (**justifying**), questioning-answering and a final resolving sequence similar to the pattern of cooperative reasoning called **resolving** presented in section 7.3.

The identification of these sequences (patterns) of locution modifiers is the first step towards the construction of reasoning strategies. These strategies should be able to enact these patterns of cooperative reasoning in an *intelligent* way. We are still at a very early stage of the development of this framework, and our aim in this dissertation is only

to provide the representation schemes that can capture these patterns of reasoning. Their animation by means of reasoning strategies is the subject of future work.

8.3. Summary

In this chapter a post facto rationalisation - using the representation schemes provided by CADReS - is applied to the software specification examples B and C of chapter 3.

We examined them showing that they are CADReS-derivable. We presented them as proof trees using a backwards deduction style. For each example, first we translated the commitment stores into the new notation. Then, starting from the resulting commitment stores, by only applying CADReS rules, we returned to empty - thus *healthy* - commitment stores.

Finally we try to identify bits of this decomposed chain of reasoning that are similar to the patterns of cooperative reasoning presented at the end of the previous chapter.

Chapter 9

Conclusion & Future Work

Negotiation permeates many aspects of our everyday life. Normally, the accomplishment of a task involving more than one party is by means of agreements, commitments and compromises. Human organizations, being based on team activity, strongly rely upon negotiation. The process of software specification exemplifies this kind of activity.

Cooperation in the work place is increasingly becoming a major issue in business, industry and in academe. As a result of this, different types of users are sharing and working on common information. Tools and methodologies are needed to instigate, support and structure this interdisciplinary debate. Cooperative work can be seen as the generation of language acts and conversations (Winograd 1988). Conversation is a mechanism for generating commitments.

Computer-Supported Cooperative Work (CSCW) is an emergent research field, which intends to study the roles and working relationships among groups of people and groups of computer systems. Computational models based on dialectical reasoning can be successfully applied to problems requiring negotiation.

In this dissertation we developed a framework for dialogue reasoning systems. This framework evolved from a formalism for the analysis of dialogue created by Hamblin and extended by Mackenzie. It comprises a commitment calculus and a dialogue action reasoning system.

An original contribution of this thesis was the work developed on

commitments. Hamblin's and Mackenzie's formalism did not provide us with a structured way to deal with the commitments inside the commitment stores. Having this in mind, we started by looking at the way deontic logic dealt with the notion of commitment. Based on that we tried to develop a commitment logic. This logic failed to capture the *delayed realisation* aspect that we attributed to commitments. We moved to a commitment calculus using a membership semantics. This time we approached the notion of commitment from the *awareness* point of view, preserving some of the important features of the deontic approach previously tried.

We applied this framework to a small case originating from software specification, focussing on its cooperative and group aspects. We tried to show that this framework is suitable for capturing and representing some of the cooperative aspects characteristic of group activities. In the future we want to study the use of negotiation strategies (van Eemeren and Grootendorst 1984) for manipulating CADReS.

The framework as it stands now is still in an embryonic stage. There is a lot to be done in respect to the calculus and to CADReS. The commitment calculus is still incomplete. It needs a lot of testing and there is plenty of room for improvement. We want to reassess the work done on commitment logic and try to link it to the calculus. This development together with the use of deontic operators within CADReS' axioms, will probably make this framework more capable of handling problems that involve negotiation. A further improvement will be the extension of CADReS from a *two-party* system into a *N-party* one.

We also intend to extend this dialogue reasoning system, by using the notions of intention, belief and knowledge in a way similar of that we have been using commitment. Intention stores, knowledge stores and belief stores will be created and intentions, knowledge and beliefs will be established and discharged by locution modifiers in a way similar to that envisaged for commitments. A new set of axioms or rules shall be devised for interconnecting theses stores, i.e. for prescribing the effects that updatings in any of the stores will cause in the other stores.

The future use of this framework for the development of groupware - which is software intended for CSCW applications - could give us more insight into the process of software development, especially from the team activity point of view, and could also give valuable feedback for improving the framework itself. This framework seems to suit applications like software configuration management (Finkelstein and Fuks 1990) where specifications (versions) are treated as commitments that are established, updated and discharged by members of the software development group. Tools for debugging could be developed on the light of mechanisms for recovering faulty dialogues.

An immediate advantage of using this framework is that group awareness is a natural consequence, and that group work support systems based on it will naturally tend to meet the end-users' language capabilities. We believe that this framework could be a source of inspiration for the design - and in the future for the development - of user interfaces management systems.

There are many other applications to this framework in computing. CAD (computer-aided design) and CAM (computer-aided manufacturing) could benefit from better user interfaces. In the subject of distributed reasoning, it could be applied to the detection of mutual consistency in distributed databases. It could help in the design of word processing software with a view to co-authorship and collaborative editing systems. Finally it could be used in the fast developing field of multimedia, for the provision of argumentative structures for computerised conferencing systems.

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