RECOS: A REQUEST-COMMITMENT SUPPORT MODEL

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Abstract

Organizational work often requires cooperation among workers to achieve task completion. One type of cooperation can be described by the pair <request, commitment>, where a "commitment" is defined as an agreement with the requester to carry out the requested action. When a worker receives a request, he must decide what to do with it. In general, many requests demand the responder's future action, and require substantial resources to complete. For these types of requests, the worker goes through a reasoning process to decide whether he should commit to doing the requested work. The research question of this thesis is: can we build a computerized system to support an individual's reasoning process in establishing a commitment? In this thesis, a computer-based Request-Commitment Support (RECOS) model is presented in attempting to answer this question.

The RECOS model is primarily based on the commitment theory in sociology, the social rule system theory, the contract theory, and artificial intelligence techniques. It proposes that the most relevant factors determining an agent's commitment are: 1) resource gains/losses, 2) the agent's competence for fulfilling the requested action, 3) requester, the relationship between the requester and responder, and the related others' expectations of the agent's decision about the request, 4) organizational regulations, and 5) the agent's previous commitments.

A computer-based system built on RECOS would assist a user to select the relevant factors and to evaluate these factors, as well as to integrate the evaluation results, in order to make a better justified and consistent commitment. Specifically, it would be able to provide a user with the following support which, we believe, is not typical of traditional decision support systems:

- Alerting the user when he makes a commitment that conflicts with prior commitments
- Suggesting those individuals that the user can ask to work jointly on the request
- Considering sentimental attributes
- Conducting simple, single-issue negotiation with the requester or other collaborators
- Automatically processing standard requests
- Providing limited learning capability (i.e., through case base) in handling non-standard requests

A user evaluation of the model has been conducted and the feedback appears promising. A prototype based on the model has been developed using Turbo-Prolog to demonstrate how a system built on the model operates.

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Chapter 1

Introduction

Organizational work often requires cooperation among workers to achieve task completion. One type of cooperation can be described by the pair <request, commitment> [FlGrHW 88], where a "commitment" is defined as an agreement with the requester to carry out the requested action. In other words, when a worker initiates a request for a commitment from his peer, cooperation is reached if the peer replies with a commitment and actually fulfils the commitment in accordance with the agreed upon terms. Initially, when the peer receives a request, he must decide what to do with it. In general, many requests demand the receiver's future action and require substantial resources to complete. For these types of requests, the worker goes through a reasoning process to decide whether he should commit to doing the requested work. Our research question is: can we build a computerized system to support an individual's reasoning process in establishing a commitment? In this thesis, we present a computer-based Request-Commitment Support (RECOS) model to attempt to answer this question. In the remainder of this chapter, we will discuss the background and motivation of this research, set up the thesis objectives, and present the outline of the thesis.

1.1 Background and Motivation

Since the early 1980s, information systems researchers have been modelling organizational activities based on the "commitment" concept. A number of models for supporting agent commitments have been proposed [Fikes 81, FlGrHW 88, Koo 88, HaJaRo 90, Bond 90]. Some of them focus on modelling organizational activities from a collective perspective (e.g., [Fikes 81, Bond 90]); and some of them focus on inter-agent communication and commitment maintenance (e.g., [FlGrHW 88, Koo 88, and HaJaRo 90]). Although they are important for understanding and supporting organizational activities, none of these models has fully incorporated the reasoning process employed by a person to commit to something (e.g., how

a commitment is reached). Consequently, there is no sufficient support provided for such a process. We agree with the observation by Bhandaru and Croft (90, p.340) that "there is a patent lack of theories of individual activity in cooperative environment." We believe that research about an individual's reasoning process for a commitment and the provision of computerized support of that process are useful and will provide the following benefits: 1) a better understanding of an individual's reasoning process in making a commitment, and 2) assistance to individuals in making better justified and more consistent commitments in handling request-commitment problems.

1.2 The Goal of the Thesis

The primary objective of this thesis is to develop a domain independent computer-based model for supporting an individual's reasoning process in reaction to a request that requires a commitment. "Agent" is used in this thesis to represent either a human being or an intelligent machine. We use the word "model " to mean a general architecture of request-commitment reasoning support systems. "Support" means that the RECOS model is not proposed as a replacement for a human being to make any commitment at the current stage. Rather, it is intended to provide assistance in determining the related factors to be considered in generating a response to a request, in evaluating such factors, and in integrating the evaluation result. In most cases, the final decision would be left to the user's discretion. The model focuses on supporting an individual's commitment making process in a multi-agent environment. Its scope covers the process from receiving a request to delivering a response.

To achieve such an objective,

- commonly related factors for making commitments should be explored, and
- the logical structure of the model should be developed.

To show the model's practicality and applicability,

- a prototype based on the model needs to be implemented, and
- some user trials and evaluations should be conducted.

1.3 The Outline of the Thesis

The thesis proceeds as follows. Chapter 2 reviews the related work. Chapter 3 discusses the "commitment" concept in greater detail. Chapter 4 discusses the factors involved in making a commitment and the structure of the model to support the reasoning process. A commitment concerns a person's future behaviour (action). Reasoned action (R-A) theory, which investigates the rationale of human behaviours, is also relevant to the commitment making process. Chapter 5 probes the relationship between the RECOS model and an R-A theory. Chapter 6 presents some applications of the model, which includes one sample application using the model and a user evaluation of the model. Chapter 7 reports a prototype based on the model, and the last chapter discusses the contributions of this work, its limitations and its future research directions.

Chapter 2

Related Work

In this chapter two types of research are reviewed. One is past computer-supported collaborative work based on commitment; the other is research which we believe is related to the RECOS model.

2.1 Past Computer-Supported Collaborative Work Based on Commitment

Since the early 1980s, the commitment concept has been increasingly used to model organizational activities by information systems and artificial intelligence researchers. Their work is reviewed in this section.

2.1.1 An Early Work

An early work using the commitment concept to model organizational work is Fikes' commitment-based framework [Fikes 81]. He observes that the primary work of an agent in an organization is to make and fulfil commitments to other agents. Each agent has a set of functions to perform. Each function consists of a number of task instances with their preconditions. When the preconditions are met for a task instance, the agent will perform that task. Fikes' primary thesis is that a commitment to an action is bounded by a set of conditions, but the structure and content of the conditions are not elaborated.

2.1.2 A Commitment Maintenance Model

[Koo 88] presents COMTRAC, a model for supporting agent commitments in a multi-agent environment. The author argues that, in organizations, agents cooperate to accomplish certain tasks via commitments. Contracts are used in COMTRAC to record commitments between agents, and a contract is represented by a set of terms and qualifications. A term specifies the tasks to be performed, and a qualification defines the conditions that must be met by the time the tasks are performed. A qualification could be nil, or it could be another term followed by

its qualification. In this way, COMTRAC links all related commitments into a commitment network, which is called a contract portfolio. When an unexpected event occurs at a node of such a commitment network (e.g., an agent cannot fulfil its commitment as promised or planned), the related agents need to adjust their commitments to fit the new situation. COMTRAC provides support for this justification process in terms of recording and tracking the involved agents and commitments. This work does not cover how a commitment is generated and the rationale of a commitment.

2.1.3 A Domain Dependent System

CoNeX, a project done at the University of Passau, proposes an integrated model for supporting group work in software development projects [HaJaRo 90]. It includes three models: 1) a group model specifying the team's organizations, task definitions, and resource allocations, 2) a conversation model defining a multi-agent communication protocol, and 3) a process model containing software development knowledge and tools. A contract, representing commitments, is used to describe the social agreements on actions. CoNeX provides support to fulfil commitments (e.g., for a commitment to transform an analysis result into a logical design, CoNeX supplies the user with tools to do the transformation and to evaluate the result), and to maintain commitments (e.g., tracking which agents are involved in the commitment and the current status of the commitment). However, there is no direct support for an agent's reasoning process for making a commitment.

2.1.4 Formal Reasoning on Commitment

A well recognized work of formal reasoning related to commitment is done by Cohen and Levesque (90). They attempt to model the relationships between belief, commitment, and action using formal logic. A commitment is defined as a persistent goal. Belief mainly concerns whether the agent believes the commitment is achievable, achieved, or no longer achievable. The relationship between act, belief, and commitment is that the agent will act to reach the goal until he believes that the goal has been achieved, or it is not achievable, or it is not necessary to achieve the goal anymore. For example, when it is raining, the agent may commit to getting an umbrella. He will try to get an umbrella until he believes that 1) he has obtained an umbrella,

or 2) it is impossible to get an umbrella, or 3) the rain has stopped and the action is no longer necessary [Gasser 91]. The agent's beliefs and commitments must be consistent (e.g., an agent will only commit to the action that he believes is achievable). Further, an agent not only adopts a commitment but also believes that he will actually fulfil the commitment. However, how a commitment is established (e.g., factors related to establishing a commitment and motivations for an agent to adopt a commitment) is not discussed.

2.1.5 An Organizational Model Based on Commitment

[Bond 90] models organizational and agent behaviours based on commitment. An organization is viewed as a set of agents with mutual commitments. A commitment is looked on as a constraint which binds an agent to perform a course of action, to hold a belief, or to attempt a goal. It specifies some features of commitment. Commitments are social (i.e., a commitment is a relationship between agents and is based on the trust and expectations of related agents). Commitments require agent integrity (i.e., agent behaviours should be reasonable, predictable, and reliable). Commitments also require resources. More specifically, a commitment is made based on: 1) the available resources, 2) the expectations of actions taken by other agents and resources supplied by them, 3) the expectation of supplying resources to other agents. As agents are interlinked through commitments, and each agent may be involved in many of them, the total commitments in the system must be integrated and consistent (e.g., all agents should have consistent beliefs under the same context and time interval). An Agent's commitments to all other related agents should be consistent with those agents' expectations of him. These guidelines are useful for modelling multi-agent systems based on commitments. However, regarding how a commitment is made by an individual, this work mainly concerns the constraints that a commitment must meet and resources that are needed to fulfil the commitment. Very little is mentioned about an agent motivation for making a commitment.

2.2 Other Related Work

Some research in the field of artificial intelligence and information systems, such as competence assessment, negotiation, and belief reasoning, were not built for modelling commitments.

However, we observe that the principles and results in this research could be beneficial to our work, so, we will briefly discuss it in this section.

2.2.1 Competence Assessment

The essential idea of the competence assessment [VoKaDL 90] is to estimate the solvability of the problem and the agent's capability to solve it before an agent actually solves the problem. The requirements for solving the problem and the match between the requirements and the available resources are major issues in evaluating the competence of an agent. Although a general method for conducting such an assessment is not yet available, the ideas presented in this research can be used in the RECOS model.

2.2.2 Negotiation

"Negotiation is a form of decision making in which two or more parties talk with one another in an effort to resolve their opposing interests." [Pruitt 81, p.xi]. When an agent makes a commitment, negotiations will very likely occur as the requester and the responder may have different interests. A lot of work has been done on negotiation, but we will not discuss it at length in this thesis. Interested readers are referred to [ChaWoo 91]. A detailed negotiation process is beyond the focus of the RECOS model. However, the initiatives of a negotiation and the results from the negotiation should be considered when an agent makes a commitment.

2.2.3 Belief

An agent's beliefs are opinions or conditions held by the agent about the environment, other agents, or himself [Konoli 85]. Thus, belief is subjective. Something believed by an agent may not necessarily be true. In intelligent systems, an agent's beliefs and his reasoning mechanisms are normally separated from domain dependent problem solving mechanisms. A belief subsystem usually includes a set of basic beliefs which are called explicit beliefs, and a set of belief inference/derivation rules. From the basic belief set and the inference rules, some results, called implicit beliefs, can be derived. A belief system must be consistent, i.e., it should not believe both A and not A, explicitly or implicitly. Otherwise, meaningless results would be produced.

There are primarily two kinds of requests which need a belief subsystem's attention [Konoli 85]: 1) given a statement, query the belief system to find out whether it should be believed by the agent; 2) since the basic beliefs or the inference rules could be wrong, when any of them or a derivation of them conflicts with new knowledge or fact, revise the belief system to maintain its consistency. We call the first issue "belief reasoning" and the second "belief revision" or "belief maintenance". There is extensive research in each of these two fields. Interested readers are referred to [Konoli 85, GenNil 87, McArth 88, Doyle 79, DeKlee 86, and MasJon 89]. The RECOS model will not look into any specific belief reasoning or belief maintenance mechanisms. However, the research results from this area can be applied to implementing the RECOS model because people make commitments based primarily on their belief systems.

2.3 Summary

In the past decade, people have tried to model and support collaborative work based on commitments. This suggests a new research direction, and, hopefully, sets up a new foundation for information systems and distributed artificial intelligence research [Hewitt 91]. We believe that the trend is plausible, and, in particular, researchers have turned their attention to sociology and other social sciences. An organization is a small society that should be studied using social science theories such as sociology and social psychology.

We share the belief with Fikes (81) and Bond (90) that agent mutual commitments link organizational activities together and get tasks accomplished. We also share the belief with Flores and Ludlow (80) that making, maintaining and implementing commitments constitutes a large percentage of organizational work. Unfortunately, very little work has been done in the area of studying and supporting an agent's reasoning process in making a commitment. We believe that the major difficulty is that there are a lot of uncertainties in making a commitment, and the reasons behind a commitment can be quite complicated or context dependent.

Although it seems impossible to build a fully automated commitment handling system, we

observe that there are still some commonalities in making a commitment. For example, certain factors are always considered and evaluated when a commitment is being made (e.g., resource gains and losses, interpersonal relationships between the involved parties). Motivated by this observation, we attempt to solicit these factors and to explore the possibility of using them in building a reasoning framework for making commitments. This is done by developing a computer-based model for supporting an agent's reasoning process in reaching a commitment.

Chapter 3

Commitment

Commitment is a fundamental concept in the RECOS model. In this chapter we will provide a definition of the concept of commitment, review sociological research about commitment, and discuss the relationships between commitment and other related concepts.

3.1 The Commitment Concept

Webster's Dictionary [Gove 67] defines commitment as: "1. the act of doing or performing something; 2. a) the obligation or pledge to carry out some action or policy or to give support to some policy or person; b) the state of being obligated or bound." The second definition, which emphasizes the binding and constraining of someone to something, is widely used in sociology and social psychology [Gerard 68, Kiesle 71, Brickm 87, Becker 60, and Gerson 76]. This definition has also been accepted by information systems and artificial intelligence researchers [Bond 90, Koo 88, Hewitt 91, Gasser 91]. Adapting this definition of commitment for our purposes (i.e., responding to another agent's request), we define commitment as an agreement by an agent to the requester in carrying out the requested action. As soon as a commitment is made and delivered to the requester, the committed agent is bound by it. A commitment should be fulfilled in accordance with the agreed upon terms unless the requester withdraws his request or fails to meet his responsibility, or the involved parties agree to modify the terms or cancel the agreement. On the other hand, when the requester receives the commitment response to his request from the other agent, he will also automatically be bound by the terms presented in his request unless some further negotiation takes place. In this thesis, 'commitment' refers not only to an agreement to carry out the requested action but also the fulfilment of it.

A commitment does not always involve multiple agents. A person may commit himself to a certain cause or goal (e.g., one may commit to spreading the Gospel or to pursuing a graduate

degree) [Brickm 87, Bond 90]. In this case, the commitment may not be stimulated by an external request and no other agents are directly involved. We consider this type of commitment a personal commitment, and it is a special case of the definition given in this section.

3.2 Commitment from the Sociological Perspective

Commitment has been studied in sociology for a long time. Organizational commitment study, an area investigating the factors that contribute to bind a person to an organization, has enjoyed much attention from sociologists.

A well known discussion on commitment is Becker's "side bets" notation [Becker 60]. In his opinion, one's commitment to an organization is determined by the rewards and costs (side bets) associated with the organizational membership. Becker concludes that a person's commitment to an organization could be determined by his previous commitment to the firm's pension plan, by others' expectations that he will not change companies too often, or by his investment (e.g., experience) in the organization. Another point made by Becker is that the effect of the related factors on a person's commitment is determined by the individual's own value system.

Becker's side bets argument on commitment has been supported by a number of empirical studies. Alutto et al. (73) did a survey with a sample of 318 school teachers and 395 hospital employed nurses. The findings suggest that individual organizational transactions and the accrual of side-bets or investments are crucial to an understanding of the commitment phenomenon. Mattaz (87) conducted an empirical study on the relationship between work satisfaction and organizational commitment. He found that it is not job-tenure that produces greater commitment, but high levels of rewards and satisfaction, which are correlated with tenure. Sayeed (89) analyzed data collected from 204 managers, and his results indicate that the longer an individual has been with an organization that has good fringe benefits, cordial management-subordinate relationships, and positive organizational policies, the greater the level of commitment and the period of attachment to the organization.

Becker's and others' findings have general implications, i.e., a commitment to something is usually constrained and motivated by rewards and costs associated with such a commitment. A person's previous commitments (i.e., side bets), play an important role in identifying these rewards and costs.

Gerson (76) furthers the study of commitment by extending Becker's work. Several points from his work are worth mentioning. First, a person participates in different settings via commitments. His commitments in all settings are interlinked and thus form a commitment pattern, which Gerson calls sovereignty:

> "I shall call the overall organization of commitments associated with any delimitable social object the sovereignty of that object." (p.798).

Assuming that people behave consistently, making a new commitment or changing an existing commitment should be consistent with this commitment pattern. Thus, to understand an individual's commitment behaviour, one should not isolate a specific situation but should take his commitment pattern into consideration. Second, a commitment can be represented by resources invested and produced. "Participation in any situation, therefore, is simultaneously constraining, in that people must make contributions to it, and be bound by its limitations, and yet enriching, in that participation provides resources and opportunities otherwise unavailable." [Gerson 76, p.797]. Finally, resources can be classified into categories: money, time/schedule, skill, and sentiment. The details of the resource categories will be discussed further in section 4.2.1.

3.3 A Formulation of Commitment

Wand and Woo (91) define commitment using concepts from Bunge's Ontology [Bunge 77, Bunge 79]. Ontology is a branch of philosophy dealing with models of the world. According to this theory, everything in the world at a given time has a state (stable or unstable), and the transition from an unstable state to a stable state is guided by transition laws. Commitment is defined by the pair <unstable state, transition law>. A thing in a stable state will assume an unstable state only as a result of an external event. Thus, an external event serves as both a

trigger to and the input mechanism for a commitment to be undertaken. Conceptually, our model fits this formalization well. More specifically, an agent can be viewed as a thing. A request from another agent is an external event to the agent, and the rationale to commit or reject the request can be looked at as transition laws. Rejecting a request or committing to a request (followed by the execution of the commitment) would put the agent in a stable state. RECOS' focus lies in exploring the major factors to be considered by the transition laws for making commitments and in supporting an agent in the evaluation of these factors.

3.4 Commitment vs. Decision

Decision and commitment are closely related concepts. According to Webster's Dictionary [Gove 67] decision has two basic meanings: (1) the act of deciding, and (2) a determination or conclusion arrived at.

Conceptually, there are some differences between commitment and decision. Commitment is a concept which stresses an agent's persistence in doing something, and it lasts for a certain period, usually until the commitment is fulfilled. Decision (as an act of deciding) occurs at a specific point in time. Commitment emphasizes an agent's obligation to something, or being bound to something. As Gerard [68] points out, commitment is irrevocable. A decision (as a conclusion arrived at) may not be so. Frequently, people make arbitrary decisions but are not serious about them, so often fail to fulfil what they have decided. "Only those decisions bolstered by the making of sizable side bets will produce consistent behaviour. Decisions not supported by such side bets will lack staying power, crumpling in the face of opposition or fading away to be replaced by other essentially meaningless decisions until a commitment based on side bets stabilizes behaviour." [Becker 60, p.38].

Decision and commitment are, however, closely related. If the decision-maker is expected to commit to what he decides, such an expectation will produce a warning effect for the decision-maker when a decision is being made [JanMan 77]. As mentioned in section 3.2, the decision-maker's commitment pattern will constrain his decision on a related issue. For example,

committing to take care of his father might lead to a person's decision to live with his father, or committing to buying a house might motivate a person to save money for a down payment.

Nevertheless, according to the definition of commitment used in this thesis (section 3.1), the reasoning process that RECOS intends to support is a specialized decision-making process, which basically deals with a binary decision-making problem (i.e., agree or not to carry out the requested action) and the requested action is predefined. For example, "Would you join us for the party tomorrow?" is a binary decision-making problem; it has a clearly defined action (come to the party), and the decision would be "yes" or "no" to this request. On the other hand, a general decision-making problem could be much more complex and the alternatives for choice could be numerous. For example, "How much should I spend on entertainment if I win a $10,000 lottery?" is not a binary decision-making problem because it could have numerous alternatives (spending $0 to $10,000 on entertainment) rather than "yes" or "no"to choose from. From this discussion we see that the request-commitment problems that RECOS proposes to cope with is better structured than, and a sub-set of, general decision-making problems. Therefore, we call RECOS a request-commitment support model rather than a general decision support model. In order to make a consistent and better justified commitment, research results of commitment study (e.g., sentiment and commitment interlinks) should be considered.

3.5 Commitment vs. Contract

Another related concept to commitment is contract. Contract is defined as "an agreement between two or more persons or parties to do or not to do something." [Gove 67]. It is a widely used term in law, sociology, and economics [Macnei 80, BarOuc 86].

The commitment concept (see section 3.1) used in this thesis is closely related to the concept of contract as it is defined above. The request receiver commits to carrying out the specified action and the requester commits to the terms, if any, described in the request. These tightly bound commitments make up a contract.

In terms of work done in the area of contracts, Macneil (80) characterizes a number of factors related to contractual relations. Because of work specialization, people perform utility exchanges. However, he claims that contractual relations are not simply economic relations but also personal relations. Furthermore, contractual relationships usually involve many people and require role integrity (i.e., contracted parties should behave consistently and in a predicable way). It is a relationship of cooperation, and the involved parties need to share and divide the benefits and burdens. The power of involved parties would affect contractual relationships. A contract has a binding effect, and the involved parties are obliged to fulfil the contract.

Some of these factors (i.e., role integrity, binding effect, agent cooperation, and multi-party involvement) will be taken as assumptions in RECOS. The others will be directly reflected in the RECOS reasoning framework. In other words, RECOS is consistent with the theory of contractual relations.

We call the RECOS model "commitment support" rather than "contract support" for the following reasons: 1) it focuses on the reasoning process of the request receiver; 2) it is primarily based on commitment research results (e.g., the resource perspective of commitment and the commitment consistency viewpoint) which, we believe, provide better insight into an individual's commitment behaviour, and can be directly used for modelling agent's commitment activities, but which are not readily available or are only described on a very conceptual level in contract study; and 3) although modern contractual relations have a more general meaning, they originate from economical exchange [Macnei 80]. When people think about a contract, they may still consider it in economic exchange terms. However, the commitment concept emphasizes the sentiment factor, which is essentially different from a contract based on economic exchange terms.

3.6 Summary

In this chapter, we have defined a commitment to be an agreement to carry out the requested action. Such an agreement is not arbitrary, but will bind the committed agent to fulfil the

specified actions. Thus, a commitment must be based on solid reasoning and justification in order to reduce post-commitment regret or revocation. A reasoning process for establishing a commitment is primarily a decision-making process, which features commitment characteristics. From the discussion, we conclude that, in order to make a well-grounded commitment to a request, "side bets" and other related factors must be evaluated before a commitment is made.

Chapter 4

RECOS: A Request-Commitment Support Model

In previous chapters we have discussed that one type of agent cooperation can be represented by the pair <request, commitment>. When an agent receives a request to carry out a certain action, he must evaluate the related factors, and figure out whether or not he should commit to the requested action. To assist an agent in making a well justified commitment, there is a need to develop computer-based systems for supporting such a reasoning process. In this chapter we will present one such model. First, we clarify the boundaries of the model; next we propose a set of common factors related to handling requests that require commitments; then, we propose the model; and finally, we conclude the chapter with a discussion of the model.

4.1 Boundaries and Assumptions of the Model

4.1.1 Boundary

RECOS supports an individual's reasoning process from the time of receiving a request to the time of delivering a response with the RECOS model. In other words, it does not support communication between agents. Only the input to and output from the communication are considered.

RECOS is not intended to replace the user at the current stage. Rather, it is aimed at assisting the user to select factors for consideration, and to evaluate these factors. It also attempts to provide some support in integrating the results of the evaluations.

During the reasoning process, many types of knowledge will be required (e.g., past experience, organizational regulations, etc.). RECOS embraces these types of knowledge bases and proposes their basic contents. However, the detailed internal structure of these knowledge bases is not fully explored; only the interfaces with them are considered.

RECOS extracts a set of factors into its reasoning framework. This is basically done by applying results from the related literatures discussed in chapter 3.

4.1.2 Assumptions

RECOS is built on, or can be best used, under the following conditions:

1. Agents are consistent and trustworthy. "Consistent" means that agents committing or not committing to a request will not prohibit the fulfilment of existing commitments. For example, an agent will not commit to physically attending two separate meetings at the same time. However, if a decision would result in such a prohibition, the affected commitments should be adjusted (e.g., to negotiate with the involved agents to modify the affected commitments) when the decision is made. "Trustworthy" means that agents can be depended upon to fulfil their commitments. This enables an agent to act (e.g, carry out commitments and make new commitments) based on his own previous commitments and other's commitments to him.
2. Agents are rational, that is an agent will not commit to a request without good reasons for supporting it. Thus, the evaluation of the relevant factors is useful for making a decision.
3. An incoming request is readily interpretable by the receiver (i.e., either agents share the same language or the incoming request has been translated accurately into the language used by the receiver).

4.2 Factors Related to Commitments

As discussed in chapter 3, a commitment is determined by the costs and rewards associated with it. In order to reduce post commitment regrets, and to maintain individuals and the system in a healthy state, an agent must evaluate related factors to make a well-grounded commitment. In this section, we discuss these factors in detail. As the model is intended to handle request-commitment interactions in an organizational environment, factors such as organizational regulations, relations between the requester and the receiver will also be explored, in addition to the factors revealed in commitment research.

4.2.1 Resources

A commitment will bind an agent to a certain course of action. As pointed out by Gasser (91), to carry out such an action the committed agent needs to invest resources: "We can see a commitment as simply *the use of resources*." (p.129). Resources can be anything that is needed for, or is affected by, completing a committed action. They can generally be classified into several categories: money, time/space/material, skill/mechanism/technology, and sentiment [Gerson 76, Hewitt 91]. An action may not demand all of these resources, but one or more is needed in the implementation of an action.

Of these types of resources, money and time/space/material are self-explanatory. Skill refers to the ability of a person to perform a task or action. This may range from the technical requirements of a particular job to social management skills. Mechanism/technology includes tools, equipment, and know-how. In this thesis, skill refers to both the skill and mechanism/technology mentioned above. Sentiment is "an attitude, thought, or judgement permeated or prompted by feeling." [Gove 67]. It includes affection, loyalty, respect, esteem, or honour. It also includes reflective sentiments such as guilt, shame, embarrassment, goodwill, or reputation. Sentiment is considered a resource because carrying out certain actions might require certain types of sentiment. For example, helping a person who has failed several times to get back on track requires someone who is affectionate towards and respected by the person. Certainly, not everyone is qualified to be a helper. Therefore, the sentimental attributes of those who can help are considered to be their resources. In addition, sentimental values, like other resources, can increase or decrease. For example, a person who successfully helps others may gain more respect from them.

Sometimes, the resources could be convertible from one form to another, e.g., money might be exchangeable for material and skills. In these cases, we need to avoid double counting the same component. In addition to the basic types of resource, another kind of resources is commitments from other agents; these commitments can be directly or indirectly converted into the basic types of resources described above. As money, time/space/material, and skill are either quantifiable or testable, we call them tangible resources. Sentiment is an intangible resource.

It is worth pointing out that a commitment may not only require the committed agent's resources but also the resources of others. For example, committing to an out-of-town project may not only require the agent's time, but also other family members' time to take care of additional responsibilities while the agent is out of town.

4.2.2 Requester, Inter-agent Relationship, and Others' Expectations

As commitment in RECOS pertains to agent interactions, the merit of the requester and the relationship between the involved parties might influence the agent in whether or not to commit to a requested action. There could be many requester's properties which might affect the agent's decision about a commitment, such as reliability. In this thesis we use the word "credibility" as a general term to represent the major properties of the requester, which might affect the agent's willingness to associate with the requester via a commitment to the request. In terms of the relationship between the requester and the agent, it can be measured in two dimensions: 1) the vertical (i.e., relative power levels between the involved agents, where power means the ability to impose one's will on others; this can be political, economical, or social [Macnei 80, Simon 57]); and 2) the horizontal (i.e., close/remote). Requests from agents with different relationships with the receiver would carry different levels of strength, and thus, would usually be dealt with differently.

In addition to the relationship between the requester and request receiver, the request receiver's closely-related agents (e.g., family members, supervisor, colleagues, friends, etc.) may have some expectations about the commitment. An agent's commitment "would be a function of such things as his awareness of the expectations, the characteristics of his relationship with those who hold the expectations, and the perceived legitimacy of the expectations." [Johnso 73, p.397]. These expectations can be explicit or implicit (e.g., someone explicitly expresses his approval or disapproval of one's commitment to a request), and may or may not be connected with resource gains/losses depending on the situation and the agents involved.

4.2.3 Regulations

According to the social rule system theory [BurFla 87, pp.54-55], "an institutionalized rule

system, a rule regime, is a system of rules adhered to by actors in a particular group, organization, culture or society." It plays an important role in guiding and regulating social actions and interactions of agents in organizations. Because agents supported by RECOS are in organizational settings, their behaviours should be guided by their organizational rules or regulations. In RECOS, regulations is a general term used to represent laws, rules, procedures, or conventions in the organization. Some regulations might be mandatory, and therefore, must be followed by the affected agent; others might be suggestive and flexible.

4.2.4 Commitment Connections

According to Becker's side-bet [Becker 60] and Gerson's sovereignty perspectives of commitment [Gerson 76] (both discussed in Section 3.2), an agent participates in multiple settings and has many commitments to fulfil. These commitments are not isolated from each other, but linked together. Because of the inter-commitments relationship, previous commitments will restrict an agent's options to the current request. As pointed out by Payne and Elifson (76), once an agent is committed to a certain line of action, some formerly available lines of action are closed. Discontinuing a committed line of action would result in certain cost to the agent. Johnson (73) labels this type of cost as "cost commitment". Thus, the relationship between the current request and the agent's previous commitments would play an important role in determining his committing or not committing to the requested action.

Distributed Artificial Intelligence (DAI) research has further elaborated this point. Gasser (91, p.114) points out that "commitment of A (i.e., continued participation of A) in a course of action in any particular setting is a product of the interactions among its simultaneous participation in many other settings." He also mentions that "commitment in this sense is the outcome of a web of activity." Although Gasser makes this statement when discussing joint commitment among multiple agents, its underlying meaning is clear: commitments are interlinked, an agent's commitment to a particular situation is affected by his other commitments.

According to Gerson (76), Gasser (91), and Hewitt (91), commitments are usually linked via

resources. The commitments which share the same type of one's resources (e.g., time) are linked together by that resource. We observe that there is another type of connection among commitments, which is different from resource sharing. That is, commitments could be linked by a predefined term or relation (e.g., if an agent is committed to work exclusively for a company, accepting a job offer from another company would directly conflict with his previous commitment). In this thesis, these two types of commitment connections are called indirect and direct connections respectively. In both direct connection and indirect connection, the previous commitments will constrain an agent when considering a commitment to the new request, but in a different manner. The resolution of the conflict may also be different. For example, if there is a conflict in using shared resources and the agent wants to commit to the current request, then either the resources committed in the previous cases must be revised, or the resources required for the current request needs to be negotiated. Similarly, if there is a direct exclusive connection between a previous commitment and the current request, either the current request might need to be rejected or the previous one revoked. In RECOS, these two types of relationships are dealt with separately. Resource conflicts are handled in "Competence" Assessment and direct linkages are looked after in "Commitment Consistency" Assessment. Both of these assessments will be discussed in section 4.3.

4.2.5 Direct Gains/Losses

Any commitment involves a positive side and a negative side. The bond of these two sides will determine an agent's commitment [Brickm 87]. In RECOS, we use the words "gains/losses" as a general term to refer to the net positive/negative effects of a decision (e.g., commitment or rejection) regarding the request. The gains/losses are measured in terms of resources. A commitment to a request may produce both gains and losses of different types of resources because the resources involved may not be comparable. We use "direct" to mean that this type of gains/losses is directly linked to the request without any interference from other factors (e.g., regulations, other commitments, and others' expectations). For example, a commitment to pick up someone at the airport, which results in being paid $20 by the requester, signifies a direct gain in money. The gains/losses are classified into two categories: tangible and intangible. The tangible gains/losses are gains/losses in money, time/space/material, and skill. The intangible

gains/losses are gains/losses in sentiment. A commitment may not only produce gains/losses for the committed agent, but also for other related agents. For example, committing to a company may not only benefit the agent, but also his family. For a professor to sit on the editorial board of an international journal not only enhances his or her reputation, but also reflects on the school where he or she is employed.

It is clear that committing to a request usually involves gains/losses. On the other hand, rejecting the request may also have gains/losses. For example, a request may have an attached term: if you commit, you will be rewarded with $1,000; if you do not commit, you will be punished by a $500 fine. This $500 loss cannot simply be added to commitment gains, since the effect might be different. Thus, when one evaluates the gains/losses related to the request, it is important to consider the gains/losses for both commitment and rejection.

4.2.6 Beliefs

A commitment to an action is usually made before actually undertaking such an action. Thus, a commitment is usually based on estimations (i.e., beliefs about and/or expectations to the commitment environment, self, and related agents). Similar to Bond (90), we use belief to represent both what an agent thinks he knows about the past, and his expectations of the future.

4.2.7 Summary

Based on some sociological research on commitment (i.e., Becker's side-bet [Becker 60], Gerson's sovereignty [Gerson 76], and Johnson's cost commitment perspectives [Johnso 73]), DAI research about commitment (i.e., commitment connection and resource viewpoint of commitment [Gasser 91, Hewitt 91]), the social rule system theory [BurFla 87], and a contract theory [Macnei 80], RECOS takes the following factors into its reasoning framework for an agent making a commitment: 1) resources, including money, time/space/materials, skills, sentiments, and others' commitments; 2) requester, inter-agent relationship, and other's expectations; 3) direct gains/losses associated with the request, which can be further divided into tangible and intangible gains/losses; 4) regulations; and 5) the relationships between the current request and the agent's other commitments (i.e., commitment connections).

We recognize that the above mentioned factors are not necessarily mutually exclusive. For example, the expectations of related others and organizational regulations may also affect resource gains/losses. However, the factors other than direct gains/losses may also play an independent role in affecting the agent's decision. Therefore, they deserve separate treatment. Sometimes these factors might imply resource gains/losses but in an indirect manner. We believe that by separating these factors from the direct resource gains/losses, the agent will be better able to structure the rationale for the commitment, and will gain better insight into that rationale. As long as the user is aware of potential overlaps and tries to avoid counting the same factor more than once in different categories, the potential problem will be eliminated or minimized. We also notice that this set of factors is by no means exhaustive. These factors are used because we believe that they are most relevant and are also context independent. If one could make his commitment based on the evaluation of these factors, the commitment would be better justified.

4.3 The RECOS Model

The RECOS model is developed to support an individual's reasoning process in handling a request that requires a commitment. This is done by assisting him in selecting and evaluating the factors proposed in section 4.2, and in integrating the evaluation results. In this section, we will present an overview of the model, discuss the knowledge bases used in the reasoning process, and look into the components of the reasoning process. As we have discussed in the previous section, agent commitments are based on his beliefs about himself (e.g., skills), about others (e.g., Agent B will commit $10,000 to a project), and about the commitment environment (e.g., the recession is not over yet). Belief(s) could be applied to many of the knowledge bases and to the reasoning components, which will be described in sections 4.3.2 and 4.3.3. However, whether something is a belief or a fact is application dependent, and it is, therefore, left as part of the design considerations for system developers to consider.

4.3.1 Overview of the Model

Figure 1 shows the overall logical structure of the model. The RECOS model includes a

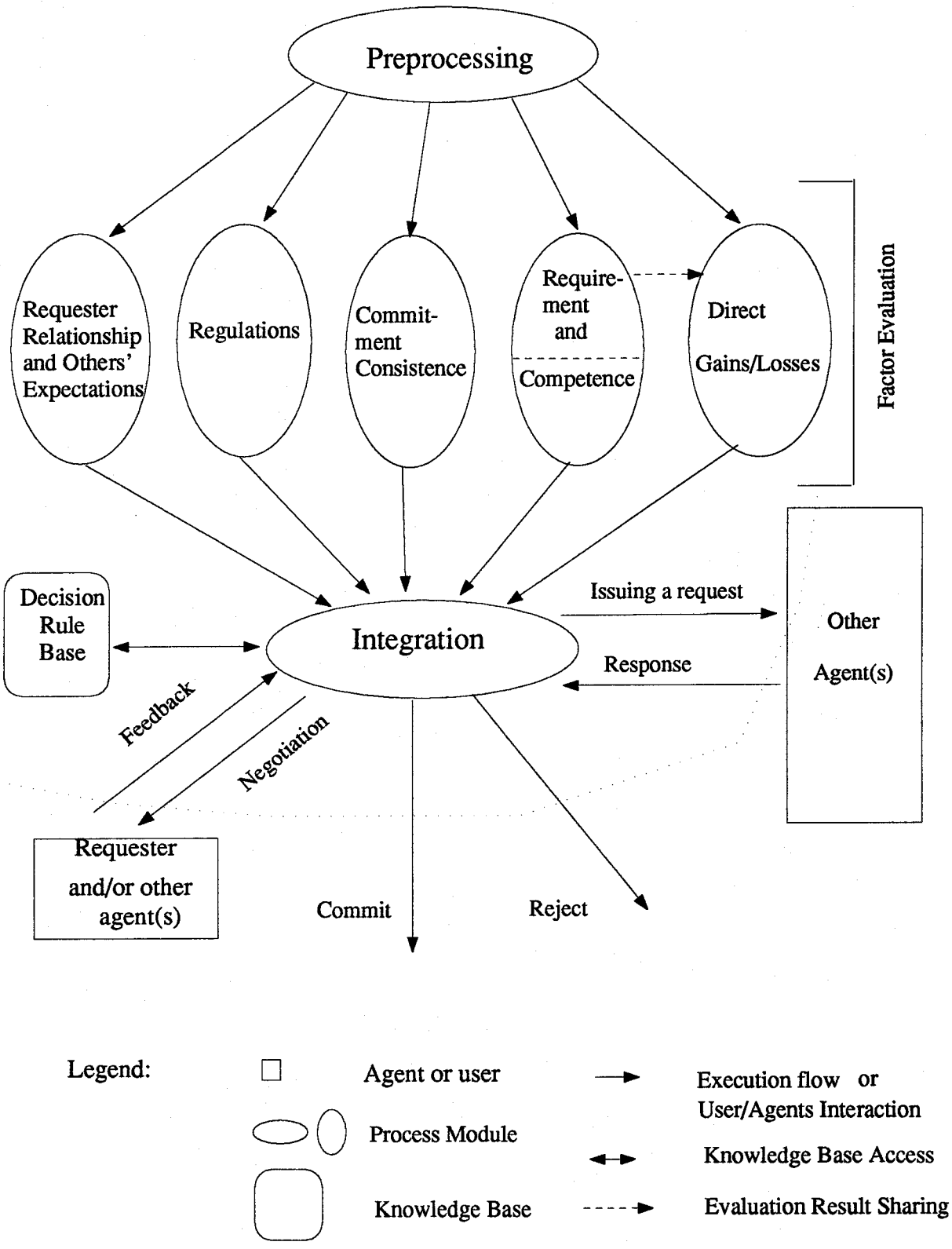

Figure-1: RECOS Model Structure and Reasoning Framework

preprocessing module, several factor evaluation modules, and an integration module. During the reasoning process, each module may need to access various knowledge bases to carry out the specified functions. These knowledge bases are currently treated as "black boxes". Only the interfaces between the boxes and the reasoning mechanism are considered. Because both the knowledge bases and processes are the critical components of the model, we will discuss them separately in the following sections (sections 4.3.2 and 4.3.3).

4.3.2 Knowledge Bases

As mentioned above, various types of knowledge may be used by an agent in his reasoning process to reach a commitment (see section 4.3.4). These types of knowledge are maintained in the following knowledge bases.

1. Topic Base: consists of all topics about which the agent has some entries of knowledge.
2. Agent Base: includes two types of information:
   1) major properties of the agent (e.g., position in the organization, etc.);
   2) major properties of other agents (e.g., skills, credibility, position in the organization) and their relationships with the agent.
3. Expectation Base: contains perceived expectations of related others about the agent's commitment to certain requests.
4. Case Base: comprises the accumulated request handling experience of the agent. Its contents are various commitment cases. Each case consists of elements closely related to a commitment, such as the relationship between the involved parties, the requirements for fulfilling the commitment, tangible and intangible gains obtained, etc. Techniques developed in the area of case-based reasoning (e.g., case representation and indexing) are applicable [Kolodn 88, Hammon 89].
5. Organizational Knowledge Base: contains organizational information that is useful to the agent in his reasoning process. Its components are:
   1) Regulations and procedures related to a particular task or position
   2) Organizational structure which describes the structure of the organization and relationships between organizational positions.

6. Resource Base: contains information related to:
   1) tangible resources that are owned by or are accessible to the agent (e.g., skills, time, space, etc.), or are committed to the agent by others (pick you up at the airport).
   2) tangible resources allocation and availability information.
   3) intangible resources, i.e., sentiment attributes, possessed by the agent.
7. Commitment Base: includes the agent's commitments, which are being executed or are waiting to be executed. The major components are: the identity of a commitment (e.g., topic), related agent(s), resources committed, tangible/intangible gains agreed upon or expected, connections with other commitments, etc.
8. Quantitative Model Base: consists of operations research, econometrics, and other quantitative models for evaluating gains/losses.
9. Decision Rule Base: includes basically two types of rules in this knowledge base. One is user predefined responses to certain requests from certain agents. The other is rules for using or integrating the factor evaluation results. Becker (60) states that one's commitment is affected by the value system which influences one's behaviour. The influence of such a value system will typically appear at the integration stage and will be reflected in the "decision rule base".

The knowledge in various knowledge bases can be retrieved through queries. A general query would look like: query_name(Condition_of_the_query, Knowledge_items_to_be_retrieved).

4.3.3 Components of the Reasoning Process

In this section, the functions of individual processes (shown in Figure 1 as ovals) of the RECOS model are discussed. The process components can be classified into three types according to their roles in the reasoning process: preprocessing, factor evaluation, and integration. The individual component functions are described below.

The preprocessing determines whether it is necessary to go through the detailed evaluation process, and whether the system has any knowledge of handling such a request. This is done by consulting the "topic base" and the "decision rule base". In the case where the request is unknown to the system, a user's involvement in making the decision is needed.

Factor evaluation, the major part of the model, consists of the following factor evaluation processes:

1. Requester, inter-agent relationship, and others' expectations assessment: This process collects information about the requester, the relationship between the requester and the agents, and others' expectations of the agent's decision about the request, using the knowledge in the "agent base", "organizational knowledge base", "expectation base", and "case base". "Organizational knowledge base" is consulted because the organizational structure may provide useful information in determining the relationship between the agent and the requester.
2. Regulation assessment: This process collects information from the "agent base", "organizational knowledge base" and "case base" on the organizational role of the agent in handling the request. The "agent base" is consulted since that is where the agent's status in the organization is stored.
3. Commitment consistency assessment: This process determines the direct commitment connection (Section 4.2.4) between the current request and the agent's other commitments. If there is any such connection, the process will also assess the consequences if the consistency is violated. This component will access the "commitment base" and "case base" to accomplish its functions.
4. Competence assessment: In terms of the resources available to the agent and his other commitments, this process evaluates his capability to perform the requested action. In order to assess the agent's capability to fulfil the commitment, the basic requirement of the commitment needs to be estimated first. Thus, in this module, there are two major functions: 1) to estimate the commitment requirement, and 2) to assess the agent's capability to fulfil the commitment. The evaluation is done by consulting the "case base", "resource base", "commitment base", and "agent base". The "commitment base" and the "agent base" are consulted because some other commitments may need to be modified, or others' commitments are needed in order to access or acquire the required resources. If this is the case, the consequences of doing so will also be assessed.
5. Direct gains/losses assessment: This process identifies the direct resource gains/losses associated with the request. This is done by consulting the "case base", the requirement

output from the competence assessment, and the information from the requester. When possible, the quantitative model may be used for evaluating tangible gains/losses.

Note that it is not necessary to go through all of the above factor evaluation processes to make a decision, and that there is no particular sequence that one must follow in using these processes. However, as a default, the competence assessment needs to be done before the direct gains/losses assessment, since the latter may need some requirement information generated in the former. During the factor evaluation, if the system does not know anything about a specific factor related to the request, the user will be consulted.

The last component of the reasoning process is integration. This process will integrate all results obtained from the above evaluations, and try to make a recommendation to the user along with the rationale. In the case where the system cannot make a recommendation, all evaluation results will be presented to the user for his judgement. If the request needs support from other agents, if a previous commitment needs to be changed in order to accommodate the request (i.e., indirect commitment connection mentioned in Section 4.2.4), or if the details of the request (e.g., resource usage, tangible reward for the commitment, etc.) need to be worked out with the requester, then the integration process will present the relevant information to the user, and wait for feedback before taking on the actual negotiation with other agents. The result of the negotiation will be used as new input to the integration process for making a final recommendation. After a reply is made, the system updates its knowledge bases (e.g., "resource base", "case base", etc.) to reflect its state and knowledge gain from the user in the reasoning process.

4.3.4 Summary

Generally speaking, to reach a decision about a request, an agent needs to go through the three stages: preprocessing, factor evaluation, and integration. During the reasoning process, the information transfers from preprocessing to factor evaluation to integration. Also, information flows between process components and knowledge bases. All of these information retrievals and transfers make the reasoning process possible. The information input and output to and from each process component, and the association of processing components and knowledge bases are

summarized in Table 1.

Module	Input	Output	Knowledge base(s) accessed
Preprocessing	Incoming request	1. Direct response to the request. 2. Go on to the factor evaluation.	Decision rule base; Topic base.
Requester, Relationship, and Others' Expectations	Incoming request	1. The credibility of the requester. 2. Relationship of the agent and the requester. 3. Expectations of related others about the agent's decision.	Agent base; Expectation base; Organizational knowledge base.
Regulations	Incoming request	1. Relationship of the regulations and a decision on the request. 2. Possible consequences of not complying with the regulation, if there is any conflict.	Agent base; Organizational knowledge base.
Commitment Consistency	Incoming request	1. Nature of the connection (e.g., exclusive, inclusive, no connection, etc.). 2. If there is a connection, commitments affected by the decision on the current request. 3. If there is a connection, the estimated consequences if the decision is taken.	Commitment base.
Competence	Incoming request	1. Requirements for fulfilling the commitment. 2. Competence status: a) competent; b) modify previous commitments; c) need others' commitments; d) not competent. In cases of b), c), and d), the reason will be specified; in case of b) and c), the potential consequences will be specified.	Agent base; Commitment base; Resource base.
Direct Gains/losses	Incoming Request; Require-ment Information.	1.Direct gains/losses for self if commit. 2.Direct gains/losses for related others if commit. 3.Direct gains/losses for self if not commit. 4.Direct gains/losses for related others if not commit.	Quantitative model base.
Integration	Incoming request; Factor Evaluation Results.	1. Commit. 2. Reject. 3. Negotiate. 4. Issue request(s) to other agent(s).	Decision rule base.

Note:
1. "Case base" is associated with all modules.

Table 1. Summary of the Information Flow in the RECOS Model

4.4 Discussion

We have presented RECOS in this chapter. Now we briefly discuss its major features and its relationships with traditional decision support systems and scheduling systems.

4.4.1 A General and Flexible Reasoning Framework

The model provides a reasoning framework for making commitments. Given the factors included in the model, we believe that it can provide support to a wide range of request-commitment problems. A reasoning process does not necessarily include all steps covered by the model, nor is the sequence of steps fixed in terms of the factor evaluation. This gives the user flexibility in handling real world problems.

4.4.2 Adaptability

When the system receives a request, it will first try to handle the request automatically by checking relevant knowledge bases. In some instances, the job will be done automatically. For example, when the user does not want to consider certain requests (e.g., paper review from certain agents), the system can reject all requests that fall into this category. In this case, the system is similar to the work presented in [MaGLRR 87]. If the above attempt fails, and the user needs assistance, then the system will use the model's reasoning structure to assist him/her. If, at any step of the reasoning process, the system does not have the required knowledge, the user will be consulted. Thus, the system is able to handle a variety of tasks including ones for which it has thorough knowledge, or those for which it has no knowledge at all. Even when the system does not have knowledge about a specific request, its reasoning framework may still be useful for the user to structure his reasoning process.

4.4.3 Relationship of RECOS and Scheduling Systems

Scheduling is the process of devising or designing a procedure for a particular objective and specifying the sequence or time for each item in the procedure [NorSar 91]. Based on this definition, scheduling problems always involve some objectives, multi-activities, time, and sequence. The RECOS model has some overlaps with the scheduling system as it is defined

above, in the sense that RECOS includes scheduling as part of its functions. However, the model's major focus is not on the scheduling problem, but on commitment reasoning, i.e., whether the agent should or should not make the commitment to the request. In this sense, the model is mainly concerned with the decision. Usually, a scheduling system focuses on how to manage or schedule the activities to fulfil certain goals or constraints and assuming the decision as a given. In the RECOS model proposed in this thesis, the scheduling function is taken as a prerequisite condition for commitment. If the requested task cannot be scheduled, the system will not commit to the request. But, even if the task can be scheduled, the agent may still not commit to the request due to other unfavourable factor evaluation results.

4.4.4 Relationship of RECOS and Traditional Decision Support Systems

In section 3.3, we claimed that the reasoning process for establishing a commitment is a specialized decision-making process. For this reason, RECOS can be viewed as a decision support (DS) model focusing on improving both the efficiency and effectiveness of decision-making in the agent interaction and cooperation domains. When dealing with routine work with which the system has thorough knowledge, the decision-making efficiency can be improved. When dealing with novice problems for which the user does not have a clear idea about what to do, the system can provide the user with some clues or hints to remind him to consider all of the relevant factors, which will result in a more informed decision. In this sense, the effectiveness of the decision would also be improved. From the problem solving style or methodology perspective, the model proposed in this thesis is different from the traditional DS approach. Taking the framework proposed by Sprague and Carlson (1982) as a representative of the traditional decision support systems (DSS) models, a traditional DSS would typically provide a user with decision-making tools, quantitative models, or flexible interfaces. RECOS is based on commitment theory [Becker 60, Gerson 76, Johnso 73] and applies artificial intelligence techniques (e.g., case-based reasoning). It aims at supporting user reasoning. Furthermore, some support provided by RECOS is not typical of traditional DSS, such as:

- Alerting the user when he makes a commitment that conflicts with prior commitments;
- Suggesting individuals with whom the user can ask to work jointly on the request;
- Considering sentimental attributes;

- Conducting simple, single-issue negotiation with the requester or other collaborators;
- Automatically processing standard requests;
- Providing limited learning capability (i.e., through case base) in handling non-standard requests;

The case-based reasoning emerged from artificial intelligence. Commitment consistency and sentiment consideration are typical features of commitment theory. As we understand it, agents interaction and negotiation are not covered by traditional DSSs either.

Chapter 5

RECOS Model and Reasoned Action Theory

A commitment mainly concerns a future action. The objective of RECOS is to establish a computer-based model for supporting a user to act rationally. From this perspective, RECOS is very much related to the Reasoned Action theory developed in social psychology.

5.1. A Reasoned Action Theory

Reasoned Action (R-A) Theory studies the relationships between a person's attitude and intention to a behaviour and the actual conducting of the behaviour. A well recognized R-A model is developed by Fishbein and Ajzen (75). In this model, a behaviourial intention is defined as a person's subjective probability to perform the behaviour, and is dependent on two factors: a personal or "attitudinal" factor and a social or "normative" factor. Since there are no other intervening factors specified between the behaviour intention and behaviour itself, a behaviour is actually determined by the attitude and subjective norm.

The attitude to a behaviour is defined as a person's general feeling of favour or disfavour toward the behaviour (i.e., the expected behaviour consequences and the evaluation of these consequences). It can be represented by the following formula:

$$\sum (bo_i * e_i).$$

Here, bo_i is an expected outcome, i, from performing the behaviour, and
e_i is the evaluation of the outcome, i.

The normative factor is called Subjective Norm (SM) since it is perceived by the person himself. Subjective Norm represents the person's perception that related others think he should or should not perform the behaviour. It can be described by the following formula:

$\sum (bn_j * m_j)$.

Here, bn_j is the person's belief about whether the related referent, j, thinks he should perform the behaviour, and
m_j is the motivation to comply with the referent j.

The model based on the R-A theory can be illustrated by the diagram shown in Figure 2.

5.2. An Innovation Adoption Model Based on Reasoned Action Theory

The R-A theory has been used in the information systems domain to study innovation adoption behaviour [Moore 88]. In Moore's Innovation Adoption Model, innovation is represented by Personal Work-Station (PWS). The dependent variable is PWS adoption behaviour, which is measured in three dimensions: a) adoption action, b) the use of the PWS to a novel domain or to solve a novel problem, and c) the degree to which the innovation is put to use. Independent variables are the individual's attitude to the adoption, subjective norm, and the voluntariness of the agent to the adoption. Conceptually, attitude and subjective norm are the same as in the R-A theory. Voluntariness is defined as the degree to which the use of PWS is perceived as being voluntary, or of free will. Attitude is measured by evaluating and summing the Perceived Characteristics of the Innovation (PCI). The PCIs covered in the model are relative advantage, image, avoidance, ease of use, observability, compatibility, and trialability. The referents used to measure subjective norm are co-workers (peers), immediate superiors, senior management, and subordinates.

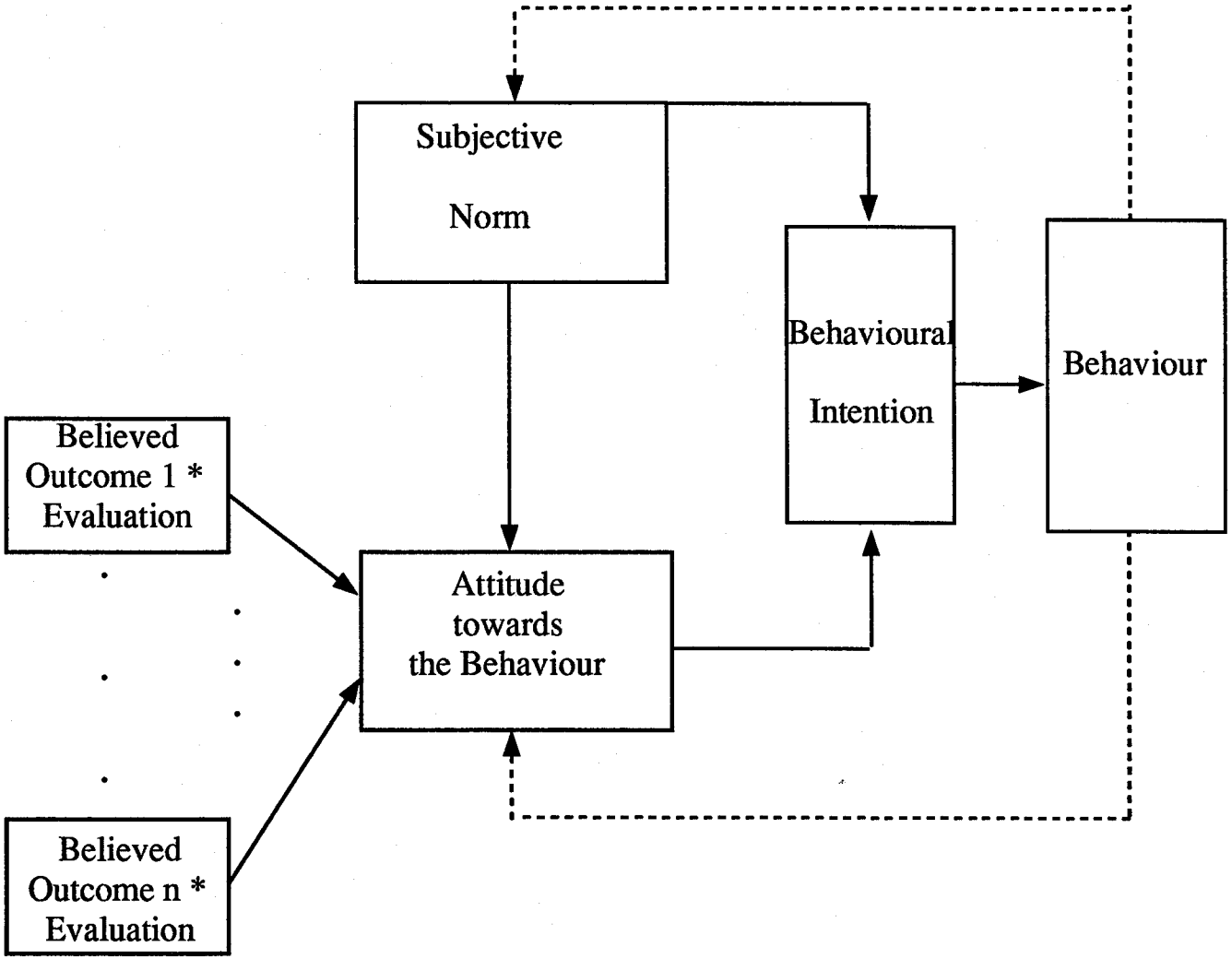

Figure 2. A Reasoned Action Model
(Adopted from Fishbein & Ajzen, 1975)

The basic meanings of PCIs used in this model are the following[1]:

Relative advantage: the degree to which using an innovation is perceived as being better than using its precursor.

Image: the degree to which the use of innovation is perceived to enhance one's image or status in one's social system.

Compatibility: the degree to which use of an innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters.

Ease of use: the degree of difficulty perceived about learning to use and actually using an innovation.

Observability: the degree to which the results of using an innovation are perceived as being visible and communicable to others.

Trialability: the degree to which an individual feels he may try out an innovation on a limited basis before adopting it.

Avoidance: the degree that the user wants to avoid the innovation because of the negative effect of its usage.

The study was conducted using a survey method, and highly correlated relationships were found between the dependent variable and independent variables. Regarding the relationship between the independent variables, subjective norm and voluntariness also affect an agent's attitude to the adoption. This model can be described by the diagram of Figure 3.

[1]All of the PCI definitions are directly adopted from [Moore 88], except for the Trialability, which is adapted according to its meaning used in [Moore 88].

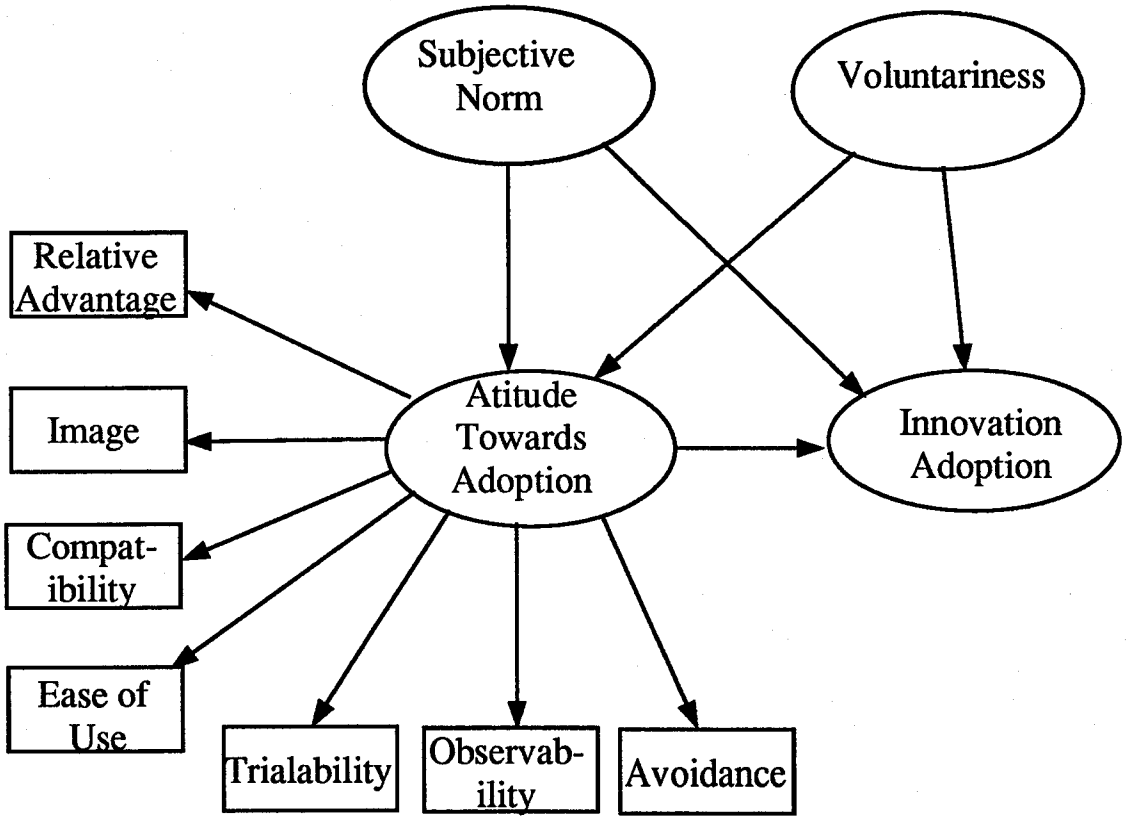

Figure 3. An Innovation Adoptation Model
(Adapted from Moore, 1987)

5.3. Relation of the RECOS Model and Reasoned Action Theory

We believe that the RECOS model fits the reasoned action framework well. According to our definition, committing to certain action is equivalent to performing the action in the future. In this sense, a commitment is comparable to the "behaviour" (i.e., performing the action) in the reasoned action theory. In RECOS, it is implied that a commitment is primarily a function of the relevant factor evaluation results. The direct resource gains/losses for carrying out the requested action, and the commitment connection effects, if any, would determine the agent's attitude to the behaviour. The inter-agent relationship and others' expectations would explain the subjective norm on a decision about the requested action. In this sense, RECOS can be looked at as an application of the R-A theory in handling Request-Commitment problems.

Comparing RECOS and Moore's innovation adoption model, we found that the RECOS model is more general, but still compatible with Moore's model. The attitudinal determinants in Moore's model can be classified into two categories. One is directly related to the benefits for the adoption, including relative advantage, image, avoidance; the other, including ease of use, observability, compatibility, and trialability, would contribute to determining the requirements or the difficulty level to successfully implement the adoption, which will affect the outcomes of the adoption. These two types of factors are covered in RECOS, but in a more general term (i.e., direct gains/losses). The subjective norm in Moore's model is directly borrowed from the R-A theory which has been discussed in the previous paragraph.

We agree with Moore that, in addition to behaviour intention (i.e., attitude and subjective norm), other factors could also affect an agent's behaviour. Such a factor presented in Moore's model is voluntariness of the agent to adopt the technology. In RECOS, two such factors are included: organizational regulations and the agent's competence to fulfil the commitment. Organizational regulations are equivalent to voluntariness in Moore's model. The competence factor is not explicitly mentioned in Moore's model, nor in the R-A model discussed above. We believe that these factors are important in addition to an individual's intention in determining his behaviour. No matter how strong an agent's intention is to a behaviour, the actual conducting of the

behaviour would be moderated by organizational regulations, especially by the agent's competence to fulfil the commitment. On the other hand, competence and organizational regulations could also affect an agent's attitude and thus intention to a behaviour.

From the above analysis, we see that RECOS models fit the Reasoned Action theory, and are compatible with another model established on a formal empirical study. The comparisons between RECOS, a Reasoned Action model, and an Innovation Adoption model based on R-A theory are shown in table 2. On the other hand, the commitment literature, as presented in chapters 3 and 4, provides more useful information and theory for developing RECOS

	A Reasoned Action Model	RECOS	An Innovation Adoption Model
Attitude	$\sum (bo_i * e_i)$	Direct Gains/Losses Commitment Connections	Relative Advantages Image Avoidance Compatibility Ease of Use Observability Trialability
Subject Norms	$\sum (bn_j * m_j)$	Inter-agent Relationship Others' Expectations	$(bn_j * m_j)$
Other Factors		Competence Regulations	Voluntariness

Notes:
1. bo_i is an expected outcome, i, from performing the behaviour.
2. e_i is the evaluation to the outcome i.
3. bn_j is the person's belief about whether the related referent, j, thinks he should perform the behaviour.
4. m_j is the motivation to comply with the referent j.

Table 2. Comparisons of RECOS Model, A Reasoned Action Model, and an Innovation Adoption Model

Chapter 6

Applications of the RECOS Model

In chapter 4, we have proposed the RECOS model for supporting an agent's reasoning process in handling request-commitment problems. In this chapter we present a sample application using the model and a use evaluation, to illustrate the model's potential usage and to test its limitations.

6.1 A Sample Application Using the Model

In this section we show a sample to illustrate a possible use and some features of the model proposed in Chapter 4. Since a complicated example would be too long and difficult to follow, we have deliberately chosen a simple scenario to demonstrate some features of the model.

6.1.1 A Brief Description of the Example

The system representing the newly-appointed Vice President (VP) in charge of R&D at a large manufacturing firm, Ron Steward, receives a request to sit on a committee to inspect the acid rain situation in the region. This requires a time commitment of the whole week of October 12 to October 16, 1992. The details of the request are as follows:

Requester: Environmental Protection Society
Request Topic: Sitting on the Acid Rain Inspection Committee
Requirements:
  Time: October 12 to October 16, 1992
  Skills: Knowledge about acid rain.

However, the VP is very busy. In particular, he has forgotten that he has a prior commitment on behalf of his company to visit an overseas research laboratory during the same period of time. Now, the system tries to assist Ron in coping with this request using its reasoning framework and the knowledge in its knowledge bases.

6.1.2 Knowledge in the System and the Reasoning Process

Some relevant knowledge is available in the system's various knowledge bases:

Agent base:

The Requester:	Very good credibility.
Relationship with the requester:	Close and important.

Organizational knowledge bases: Participating in external R&D related activities is part of the duty of VP R&D.

Resources base:

Time:	October 12 to October 16, 1992 has been allocated to another activity
Skill:	Knowledgable in acid rain issue

Commitment base: Visiting an overseas research lab from October 10 to October 20, 1992.

Now, the system tries to evaluate various factors regarding whether or not the agent should commit to the request. As mentioned in section 4.3.3, the factor evaluation sequence of the reasoning process is not fixed. For the purpose of this example, we describe the reasoning process according to the sequence shown in Figure 1.

1. Consulting the "agent base", the system knows that the requester has very good credibility. As the VP R&D in this company, his relationship with this society is close and important.
2. The system, by checking with the "organizational knowledge base", finds that participating in such an activity is consistent with company regulations.
3. For the commitment consistency assessment, the system does not find any direct connection between the request and other commitments.
4. By analyzing the request, the agent knows that the primary requirements for committing to such a request would be skill and time. Based on this information, the system evaluates the resources available to him. His time for that period is already scheduled. By checking with the "commitment base", the system discovers that the time conflict is with a commitment to visit an overseas research lab. It also determines from consulting the "resource base" that he is knowledgable about acid rain research, a requirement of the request.
5. The system does not know the detailed direct resource gains/losses related to committing

to or rejecting the request. However, it reminds the user to consider this factor by presenting this issue to him.

After the factor evaluation, the system integrates the results and presents a recommendation to its user.

6.1.3 A Sample Dialogue

In the following, we offer a sample dialogue between the system (Sys) and the user (Ron) during the reasoning process. This dialogue is simplified to highlight the major points.

As we mentioned in the previous section, the system has evaluated other factors but needs the user's input for the direct gains/losses related to committing to or rejecting the request.

1. The system presents a number of options for the direct gains/losses factor:

> 1. Tangible resource gains/losses for committing
> 2. Intangible resource gains/losses for committing
> 3. Tangible resource gains/losses for not committing
> 4. Intangible resource gains/losses for not committing
> 5. Others direct gains/losses not covered by 1-4
> 6. Exit

Ron chooses 1, 2, 4.

2. Because Ron chooses "tangible resource gains/losses for committing", the system presents the following options:

1. Money
2. Time
3. Space
4. Material
5. Skill
6. Others
7. Exit

Ron chooses 'Skill'.

Sys: What type of skill would you gain/lose if you commit to the request?

Ron: Gain knowledge of current situation of acid rain problem in this region.

3. After finishing the "tangible resource gains/losses for committing" evaluation, the system presents the following options for another choice made by Ron, "intangible resource gains/losses for committing":

1. Reputation
2. Respect
3. Loyalty
4. Esteem
5. Guilt
6. Honour
7. Others
8. Exit

Ron chooses 'Reputation' and 'Honour'.

Sys: How would the commitment to the request affect your reputation?

1. Very positive; 2. Positive; 3. No difference; 4. Negative; 5 Very negative.

Ron: 1.

Since the system interprets that Ron feels it is an honour to sit on the committee, it does not ask any questions about this choice.

4. Then, the system responds to Ron's last choice, "intangible gains/losses for not committing", with the following options:

1.	Reputation
2.	Respect
3.	Loyalty
4.	Esteem
5.	Guilt
6.	Others
7.	Exit

Ron chooses 'Reputation' and 'Guilt'.

Sys: How would it affect your reputation if you do not commit to the request?
1. Very positive; 2. Positive; 3. No difference; 4. Negative; 5 Very negative.

Ron: 4.

Since the system interprets that Ron feels guilty for not committing, it does not ask any question about this choice.

After the factor evaluation, the system tries to integrate the evaluation results and to propose a recommendation to Ron.

Sys: Based on the knowledge I have and the information you gave me, the evaluation result regarding sitting on the Acid Rain Inspection Committee is as follows:

Requester:	Environmental Protection Society;
Requester Credibility:	Very good;
Relation with the requester:	Close and important;
Commitment and Regulation:	Consistent;
Commitment Consistency:	No direct connection detected with other commitments;

Competence:

Time: No, you have a commitment to visit an overseas research laboratory during October 10 to October 20, 1992.

Skills: Yes.

If you commit,

Tangible Gains: Knowledge of current situation of acid rain problem in this region.

Tangible Losses: One week of time (The system automatically takes the tangible resource requirement as an investment);

Intangible Gains: Very positive effect on your reputation;
It is an honour to sit on this committee.

If you do not commit,

Intangible Losses: Negative effect to your reputation;
You would feel guilty.

The evaluation results are in favour of committing to the request except for the time conflict with your visit to the overseas research laboratory. I am not clear about the consequences if you negotiate with the lab to change the date of your visit. Do you think it is worthwhile to reschedule your visit in order to commit to the current request?

Ron: Yes.

Sys: I suggest you change your visit to November 2 - November 12, the earliest time during which you do not have any important commitments. What do you think?

Ron: November 2 - November 10.

Sys: Do you want me to negotiate for you?

Ron: Yes.

Sys: The negotiation is successful. The laboratory agrees to your new agenda.
Please give me your decision on the request from the Environmental Protection Society.

Ron: Commit.

Finally, the system will record this case in its "case base" for later usage.

6.1.4 Discussion

From this simple example we can note several features of a system built on the RECOS model.

1. It supports the user by automatically processing part of the reasoning process, using the knowledge in its knowledge bases. This could improve the user's efficiency and effectiveness in generating a response. For example, Ron may not know the requester well since he is new to this position, but the system, by providing such information, would save him time, and could possibly help him avoid a mistake if the factor is important in handling the request.
2. It reminds the user about conflicting commitments. Although this point appears as a scheduling problem in the example, it also applies to other types of resources.
3. It prompts which factors to evaluate, and also proposes possible factor attributes to consider. In the example, this is typically shown in the direct gains/losses assessment. Although the terms used in the example are general in nature (e.g., space, material, skill, etc.), they may still have some usefulness in reminding the user to structure his thinking. If an application system were designed for handling specific domain problems, this would be much clearer.
4. It presents to the user the pros and cons of committing or not committing. For example, if the user is not competent, the reasons are presented to him.
5. It proposes negotiation terms in certain situations.

6.2 User Evaluation

The RECOS model is based on research results from different research areas. It requires further testing to determine whether the factors considered in the model's reasoning framework are relevant in handling real life problems, and also to determine the model's limitations. Attempting to explore the answers to these questions, we conducted a user evaluation. The basic purpose of the user evaluation was to learn: 1) the relevance of the factors covered in RECOS to the reasoning process of individuals in handling request-commitment problems; 2) the weaknesses and limitations of the model. We asked users to use the model to handle a real life request-commitment problem, and then we solicited their comments about the model.

6.2.1 The Design of the Prototype for the Evaluation

To fulfil the evaluation objectives, we wanted to represent the model in a more structured format rather than a general description. However, by showing an implemented prototype of the model, we feel that the user might be distracted by the implementation details and not focus on the conceptual part. Given this consideration, we developed a set of questions for each of the factor categories covered by RECOS. Our intention was that, through these questions, the user would get a good idea about the model. Most of the questions were not intended for the user's precise answer, but for reminding them about the issues to think about when they made a decision about a request. The evaluation objective might be fulfilled by presenting the subjects questions on paper. However, the paper based questions are sequential in nature and the subjects basically need to go through every question from the beginning to the end. In that case, the subjects would not see the structure that the RECOS model provides. Furthermore, the subjects may also get lost or confused, since some questions are exclusive logically and not all factors are relevant to certain domain problems. Therefore, we need to present the questions in a more flexible and structured way to accurately represent the model. Based on this consideration, we coded the questions into a computerized package which provides: 1) better structure, i.e., the factors are presented by menus which mimic the model structure; 2) better flexibility in selecting factors, i.e., the user can select any number of factors to evaluate and can go back and forth between different factor evaluation modules; 3) smoother logic flow, i.e., only the necessary questions are presented to the user according to his/her choice.

After developing the first prototype, we did a preliminary test. The basic purpose of this test was to get users' comments on the prototype design and the match between the questions and the factors they were assumed to represent. At this stage, we had four graduate students try the prototype. All of them have taken at least one empirical study course. Two of them have undertaken empirical studies by themselves. We found this step was useful and constructive. Many suggestions were proposed on the question format and wording, the match between the questions and the factors they represented, and user interfaces. Based on these suggestions, the prototype was modified. Some examples of the prototype screens are shown in Figures 4 - 7. In each of the menus, there is an "Other" option offered for the user to probe any factors or

issues which are not covered by the menu options. When the user finishes the evaluation in the current menu or enters a wrong menu, he/she may quit the current menu immediately by choosing "Exit".

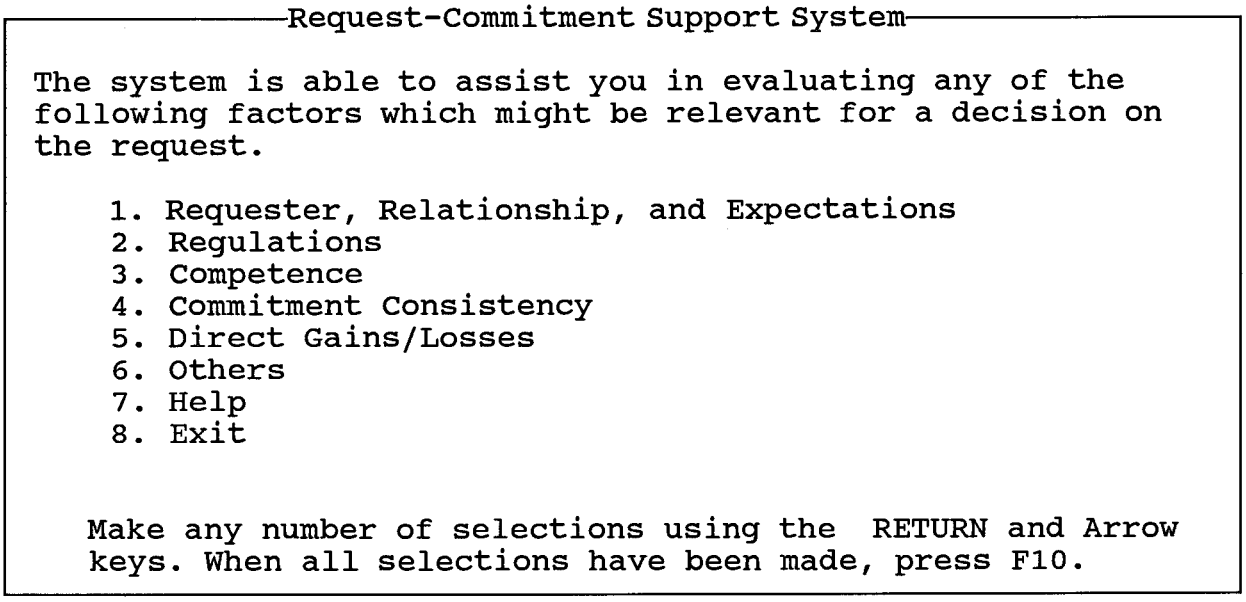

Figure 4. The main menu of the evaluation prototype

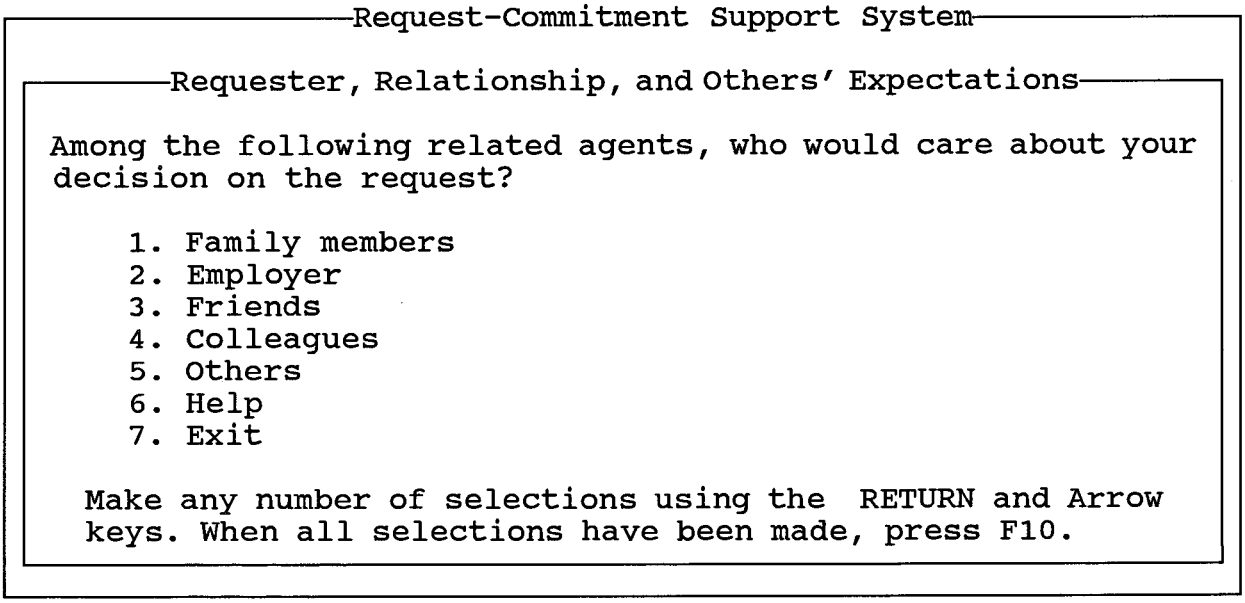

Figure 5. The others' expectations of the evaluation prototype

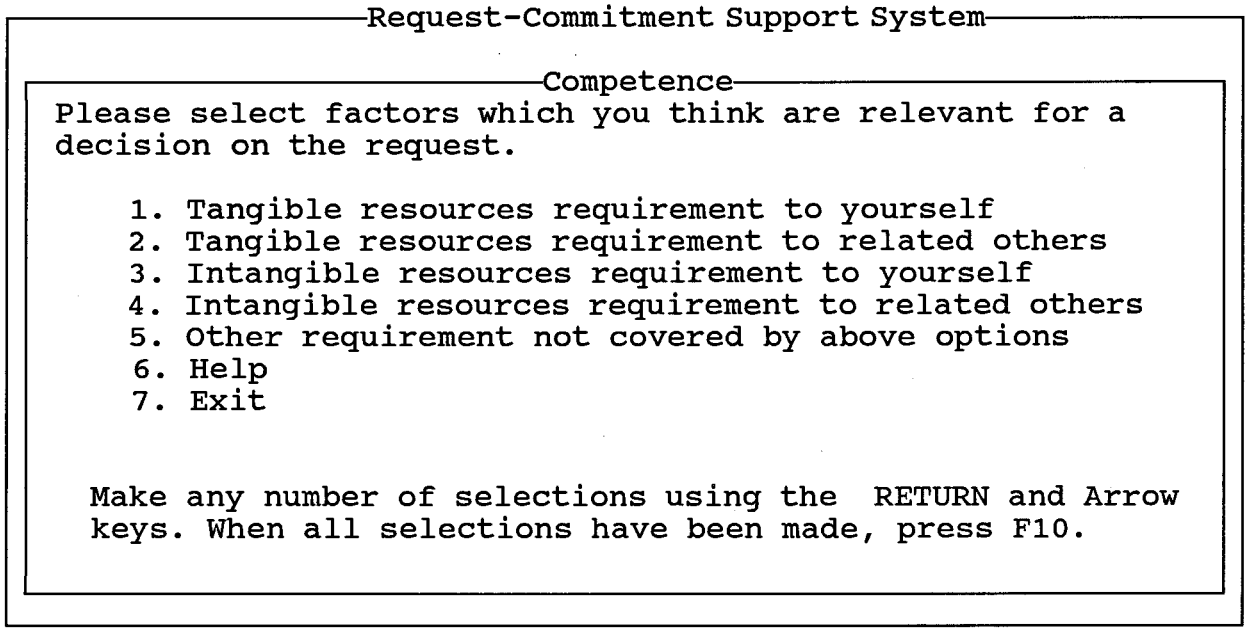

Figure 6. The competence assessment of the evaluation prototype

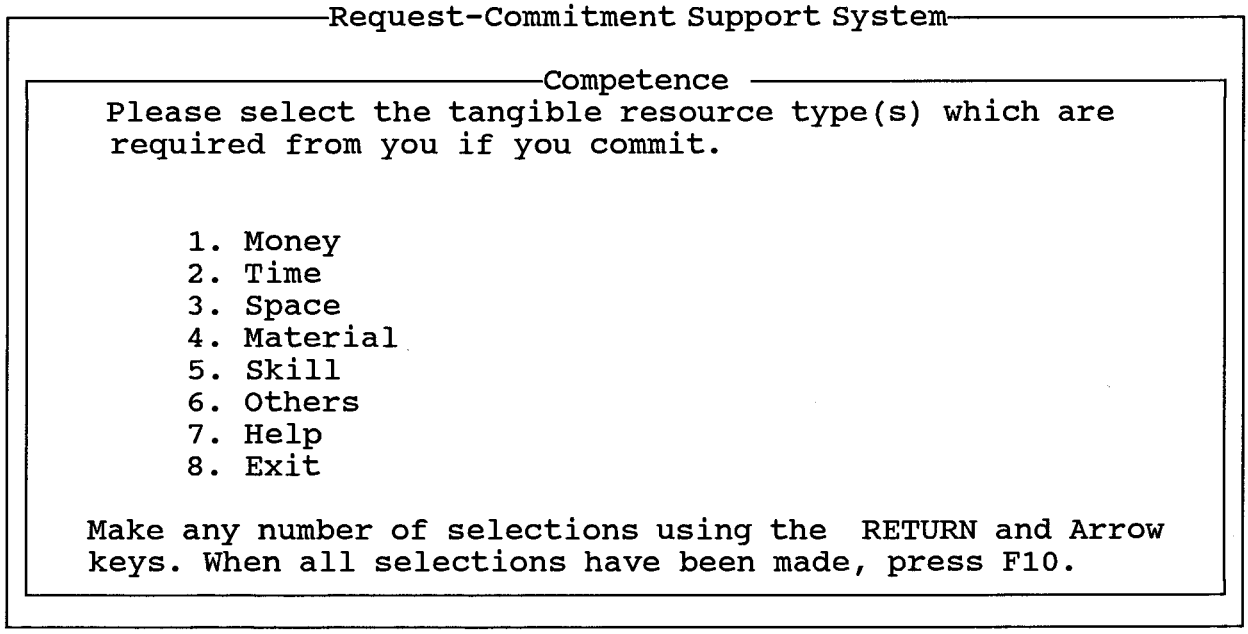

Figure 7. The tangible resource requirement of the evaluation prototype

6.2.2 The Subjects and the Scenarios

The subjects were two current M.Sc. students, two research associates, one MBA graduate, and one Ph.D. student. Since this is not a formal empirical study, they were not randomly chosen. To evaluate the model, a scenario of request-commitment problems was needed. The request-commitment problem we chose for the user evaluation was "a person you have been dating proposes to marry you." The reason we have chosen this scenario is that: 1) It is a real life problem that some adults will face, or have faced; 2) It is a relatively complicated problem requiring some serious thinking to make a decision; and probably reasoning assistance is needed; 3) It might demonstrate major features of the RECOS model. This scenario was only prepared as the backup and the subjects were encouraged to use their own examples to try the model. It turned out that no subject chose to use this example. The reason might be that it is not realistic for some of our subjects because they are already married or else do not have a boy/girl friend, or it is too personal and sensitive a scenario.

The examples used by the subjects for the evaluation were: a request from a real estate agent to make an offer for a particular house, a request from a friend to proofread a big research paper, a job offer from a company, a request from a friend for some semi-confidential information about my organization, and a request from a friend to participate in a church activity group. Among these examples, "a job offer from a company" was used by two subjects. Although some of the examples were rather simple, they happened in real life, and they did require some evaluation and reasoning according to our subjects. Another advantage for using these real life scenarios is that the subjects had already thought about them, and thus, it would be easier for them to pin point any weaknesses in the model.

6.2.3 The Conduct of the Evaluation

The study was conducted on different days and the subjects attended a trial session one by one. At least one day before the study, the subjects were asked to think about a request-commitment problem they had encountered, particularly one for which there was no clear answer. At the beginning of the study, the author briefly introduced the model and the purpose of the study. During the study, the subjects operated the prototype and the author sat beside them to answer

questions and make notes. Discussions occurred during and after the trial. Each session took about one to one and half hours, depending on the length of the discussion.

6.2.4 Discussion

Many recommendations resulted from the study. The Feedback can be classified into two categories: 1) recognition, and 2) challenges and questions.

1. Recognition

1) All subjects recognized that the factors covered by the model are relevant to their reasoning for a commitment, although they found that the weight of each factor might be different, and not all the factors were relevant to every scenario.

2) Four of the subjects remarked that a system built on the RECOS model would be useful in helping people to make better justified and more consistent commitments if the domain knowledge was built in. One subject pointed out that a system built on the model would also be useful in training users to reason rationally and structurally. The system would familiarize them with the reasoning framework, and they would continue to use the model's framework. Two of them commented that, even at this stage, it already has some prompting capability. Since the usefulness of the model was not a major objective of this study, we did not pursue which factors were prompted by the model but not considered by the subjects. Another reason that this type of information was not clearly revealed might be that most of the pros and cons about the example had been well considered by the subjects before they came to the evaluation. Without providing the detailed domain knowledge, the model might not be able to give them much more insight about the request.

2. Challenges and Questions

Since the major purpose of the study was to find out the model's weaknesses and limitations, a lot of discussions focused on this aspect of the model. The major points are summarized below:

1) Alternatives and potential commitments. One subject gave the following scenario:

"Someday a real estate agent may come to me and show me a nice house with a reasonable price. However, I might still want to look around to check other houses. Can the RECOS model help me to evaluate the alternatives and give me a comparison between them?" He also thought about another issue: "I am planning to buy a house in Vancouver. However, there may be a chance that someday an attractive job offer comes from Toronto. If I commit to buying the house now, it might conflict with my future commitment for the job. Can the model take this issue into account?"

We agree that RECOS may have limitations when it comes to evaluating alternatives or potentially related commitments. However, in real life, many request-commitment problems do not have a foreseeable alternative or a related future commitment, or they are not worth considering. For example, in the scenario of "proof-read a big research paper" used by another subject, there may not be any alternatives (e.g., committing to review another paper from someone else) other than "commit", "reject", or "negotiate". There may not be any potentially related commitments to think about either, because such a commitment can be fulfilled in a couple of days, and there is no other request-commitment problem expected. However, in real life, we do encounter a lot of request-commitment problems which involve alternatives and potential commitments. Thus, we must be aware of this issue when applying the RECOS model.

2) Moral principle and self image. Some subjects pointed out that morale principle and self image would also affect one's decision on a request. We agree, and the RECOS model has actually taken these effects into account (i.e., in sentiment). Whether a commitment is consistent or not with the agent's moral principle will directly influence his sentiments, either positively or negatively. For example, if one does something against his/her moral principles, he/she might feel guilty, shamed, or embarrassed. Otherwise, the effect of the moral principle would not be a relevant factor in the decision. Similarly, the effects of self image can also be represented by sentiment. The example used by a subject, "proof-read a big research paper", illustrates this point. The subject claimed that he "has a good mastering of written English." If he rejected the request, it would be inconsistent with his

self-image, putting other factors aside. We explain that the effect, if any, of such an inconsistency between his self-image and behaviour would actually reflect on his feeling about his self esteem and other related sentiment attributes.

3) Resources classification. In RECOS, we classify resources into tangible and intangible (see section 4.2.1) categories. One subject pointed out that skills may not necessarily be tangible since not every skill can be measured. Another subject considers only physical matters tangible. We agree that such a classification might not be consistent between subjects. Such a classification was based on the following definition of "tangible": "substantially real; conceived or thought of as definable or measurable." [Gove 67]. From this definition, some components included in skills, such as equipment, are real. Other components, such as knowledge, are also testable or measurable in some sense (e.g., know or do not know, have or do not have, etc.). On the other hand, sentiments are mostly subjective matters, which are based on one's feeling. Thus, sentiments are called intangible resources and others are called tangible resources. Nevertheless, this classification was just for the purpose of convenience. Its precise definition may need further study, but is beyond the scope of this thesis.

4) Domain specific knowledge and personal preferences. One subject pointed out, "when evaluating a request, I always consider some specific issues about the request. For example, when I evaluate a house, in addition to other issues, I also think about its locations and the safety of the area where the house is located." This implies that for evaluating a request, domain knowledge is necessary. The RECOS model is a domain independent reasoning framework, and there is no domain knowledge directly represented at the current stage. However, when an application system is developed, the factors covered in the model will be adapted to fit the domain. For example, in the real estate domain, space might be defined as location, the size of the property, the number of rooms in the house, and the size of each room; in the money category, not only the price of the house will be included, but also the extra cost for the security supplies and service might be considered; and the feelings of secure or insecure will be represented in sentiment.

Nevertheless, some domain specific issues or user specific preferences might not be fully represented by the factor categories covered in the model. But, at the integration stage, the system will apply the user predefined decision rules to the factor evaluation results to produce a recommendation. If something is specified in a decision rule, but not reflected in the factor evaluation results, it will be highlighted and presented to the user for further probing.

5) There were some other comments generated in the evaluation, such as: 1) it is too general a framework without focusing on any domain, 2) a system built on RECOS would be too big and inefficient, and 3) tools for integrating the factor evaluation results should be developed. We agree that these issues deserve further attention. However, the investigation of these issues is beyond the scope of this thesis.

Chapter 7

Prototyping

To test the model's practicality, we have implemented a prototype based on the RECOS using Turbo-Prolog [Borlan 88a, 88b, 88c]. In the remainder of this chapter we will report: 1) the objective of the prototyping, 2) the major features implemented in the prototype, and 3) the experience we have learned from this implementation.

7.1 Objective of the Prototyping

The basic objective of the prototyping was: 1) to show what a system built on the RECOS model looks like, and, in particular, how the system uses its past experience to assist the user in handling the current request; how the system uses knowledge available in its knowledge bases to assist the user to evaluate the relevant factors; and how the system interacts with the user to solicit the required information and present the evaluation result to the user; 2) to evaluate some potential problems and difficulties with implementing the model. Based on this objective and the RECOS model framework, the prototype will neither look into the detailed knowledge base structures nor include any integration tools to synthesize the individual factor evaluation results. What will be presented to the user at the final stage (Integration in Figure 1) are the results obtained from the individual factor evaluations, including the input from the user.

7.2 The Prototype Structure and Features

The structure of the prototype is presented in Figure 8. The function of each component is similar to what was discussed in section 4.3. Therefore, we will not repeat it here. What we will present in this section are its major features. The prototype we have implemented is basically an extended version of the one that has been used for the user evaluation. The major features of this prototype are: 1) flexible user interfaces; 2) "case base" application; 3) certain factor evaluation automation; 4) evaluation result report.

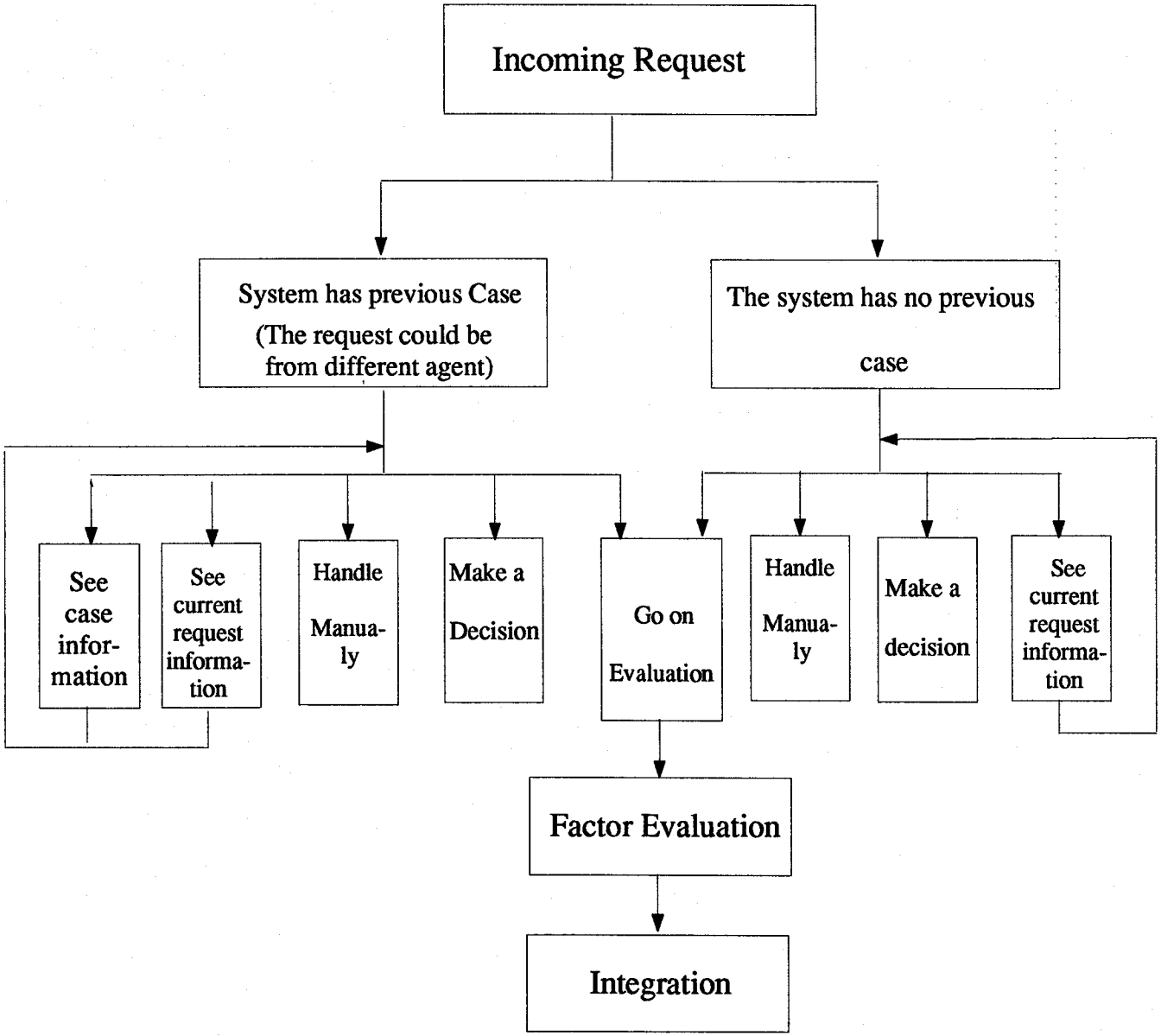

Figure 8. The Prototype Structure

1. Flexible User Interfaces

In this prototype, we maintained the user interface style used for the user evaluation, but included preprocessing, and integration. As the user interfaces in the factor evaluation stage are similar to that described in section 6.2.1, here, we mainly show the interfaces in the preprocessing and integration stages. Figures 9 - 13 are some samples of the user interface screens. The prototype assumes that it receives a request from another agent through the computer network. If there are no previous cases or predefined response for such a request, it gives the user four options to choose from: 1) Making a decision right away, 2) viewing the request information, 3) using the system to do the evaluation, or 4) handling the request manually (Figure 9). If the system has previous experience (i.e., cases) in handling similar requests, it will present the user with another set of options (Figure 10). When the system solicits knowledge about certain factors, it will show the user some possible options, and also leave the user flexibility to use his own scale (Figure 11). In this way, the user retains the maximum possible flexibility and controls the reasoning process.

2. "Case Base" Application

A major feature of this prototype is using its past experience to aid the user in handling the current request-commitment problem. Figure 10 shows that if the system has experience in dealing with a similar request, it will present the user with the decision in the previous case, and will also allow him to review the case information. The system assists the user with two types of cases. First, the system will try to find a case with the same request topic and the same requester as the current one. If this trial fails, it will retrieve the case with the same topic but from a different agent. We believe this manner of case screening would give the user the most relevant and closest past experience possible. On the other hand, the reasoning process for reaching a decision is also a knowledge acquisition process for the system. It will store the final evaluation result as a new case for future applications. When the system first encounters a request from a new agent, it will most likely need to solicit most of the information from the user. When it meets the same request from the same agent, or a different request from the same agent, or the same request from a different agent, it will be able to release the user from evaluating certain factors, such as agent credibility, inter-agent relationship, and regulations.

In this sense, the prototype possesses limited learning capability. We would like to point out that the use of cases in this prototype is a very simple application of the case-based technique developed in artificial intelligence [Hammon 89, Kolodn 88]. If a more sophisticated case-based reasoning mechanism is used, the system would be more useful.

3. Certain Factors Evaluation Automation

Under certain situations, the prototype can assess certain factors (e.g., requester credibility, inter-agent relationship) on its own, without interrupting the user. This is done by applying the available knowledge in its knowledge bases. This feature's application and usefulness have been discussed in sections 6.1.2 and 6.1.4. Thus, we will not repeat that description in this section.

4. Evaluation Report

After the individual factor evaluation, the system will present the overall evaluation results to the user for his judgement (Figure 12). This conforms well with one of the suggestions from the user evaluation, discussed in section 6.2, which was to show the factor evaluation result to the user at the integration stage. After the user reviews the result, the system will show another screen to solicit the user's decision (Figure 13).

Dear user, welcome to the Commitment Reasoning Support System.

You have a request from Dr. Gorden King. It is 'giving a seminar about commitments'.

Please choose one of the following options to proceed in handling the request:

1. Making a decision right away
2. Viewing the detailed request information
3. Starting the factor evaluation
4. Handling the request manually

Make your selection by pressing the RETURN key.

Figure 9. A preprocessing menu when the system has no experience

Dear user, welcome to the Commitment Reasoning Support System.

You have a request from John Smith. It is about 'go to dinner'. According to a previous case, you committed to a similar request from Ken Lee. I checked your resources, and found you have the resources to fulfil the requirements of the request.

Please choose one of the following options to proceed in handling the request:

1. Making a decision right away
2. Reviewing the case information
3. Viewing the detailed information of current request
4. Going on the evaluation
5. Handling the request manually

Make your selection by pressing the RETURN key.

Figure 10. A Preprocessing menu when the system has experience

I do not have the information about your relationship with Dr. Gorden King. Please define your relationships with this agent by choosing one of the options:

1. Important
2. Not important
3. Not clear
4. Self defined term

Make your selection by pressing the RETURN key.

Figure 11. Acquiring information on inter-agent relationship

Based on the information I have, I believe you have the skill and time to fulfil the requirements of the request, giving a seminar about commitments, from Dr. Gorden King. However, other factor evaluations should also be considered before making your decision, which are shown below:

The credibility of the requester:	Very good;
Your relationship with the requester:	Close and Important;
Relation to Regulations:	Consistent;
Relation to other commitments:	No direct connection;
Competence:	Yes;

If you commit,

The direct gains:	A free dinner; One day free sight seeing of Vancouver; Positive effect to your reputation; Positive effect to your respect;
The direct losses:	Two days of time;

If you do not commit,

The direct gains:	none;
The direct losses:	Feel guilty; Negative effect on others' respect for you.

==========

Press any RETURN to continue to the next step.

Figure 12. A factor evaluation result report

After reviewing the factor evaluation results about the request, giving a seminar about commitments, from Dr. Gorden King, you might be ready to make a decision now. Please choose one of the following options to proceed in handling the request:

1. Committing to the request
2. Rejecting the request
3. Negotiating with the requester
4. Others

Make your selections by Pressing the RETURN key.

Figure 13. A menu after showing the evaluation result

7.3 Discussion

From the prototype implementation we learned the following.

1. Case-based reasoning mechanism might be a major tool for implementing RECOS. An agent acts in an organizational environment, which is an open system [Gasser 91, Hewitt 91]. From the prototyping, it is clearer to the author that it is impossible and not feasible to capture complete knowledge in the system (e.g., we cannot exhaustively capture all regulations). However, through the case-based technique, the system can collect the most relevant information into the system. If a similar request repeatedly occurs, then the system would be able to provide more and more support to the user. Eventually, the user may only need to pay the minimum attention to handling certain requests, and let the system do the job for him.

2. Separating the domain knowledge from the reasoning mechanism.

   To fulfil the objective of the prototyping, a major issue was to carry the evaluation results from one stage to the next. At the beginning, we tried to use clause parameters (a clause in Prolog is similar to procedure call in other languages) to carry the information. However, when recursion (the central reasoning mechanism of the prototype) and application information passing combined together, the system behaviour became difficult to control. Later on, we

took the advantage of the database facility in Turbo-Prolog and used databases as a medium to pass the information from one stage to another. In this way, the reasoning mechanism was released from transferring data, the prototype was structured better, and the system behaviour was under control. We believe that the separation of the reasoning mechanism and the application information transferring has a general implication for implementing the RECOS model for domain applications.

Chapter 8

Conclusion

We have presented RECOS, a computer-based model for supporting an agent's reasoning process in dealing with request-commitment problems in a cooperative multi-agents environment. To conclude the thesis, we will discuss the thesis' contributions, its limitations, and future research directions in this chapter.

8.1 Contributions

The major contribution of this thesis is that it collects a set of domain-independent factors from different areas related to making commitments (e.g., commitment research in sociology [Becker 60, Gerson 76, and Johnso 73] and DAI [Gasser 91, Hewitt 91], a social rule system theory [BurFla 87], and a contract theory [Macnei 80]), it proposes a reasoning framework for applying these factors, and it presents a computer-based model to support an individual's reasoning process for making a commitment (particularly, in selecting and evaluating the relevant factors). People in artificial intelligence and information systems research have tried to use the commitment concept to model organizational activities and to support cooperative work in a multi-agent environment. However, little has been done to support an individual's reasoning process in making a commitment, and it is on this which the RECOS model focuses. Its major usefulness lies in its general reasoning framework, on which the domain application systems can be based. A prototype has been developed for the model. It is simple and preliminary, but we did learn something from the prototyping process, which can be useful for developing application systems in the future.

RECOS is not another model for decision-making which generates the best reward for the agent. It emphasizes a commitment's effects on both the committed individual and the community in which the individual is acting (e.g., by reminding the user to be aware of others' expectations, organizational regulations, and sentiments). This consideration is important because an individual's well-being and an organization's well-being are closely related [Gerson 76]. This

feature distinguishes the RECOS model from most other traditional decision support models.

The second contribution of this work is its insight into the model obtained from a user evaluation. Although the user evaluation was very simple in nature, it did reveal a number of the model's weaknesses and limitations, its potential uses, and issues that should be addressed regarding the model's application and implementation.

The third contribution is the classification of commitment connections. In commitment research, the linkage between commitments is highly emphasized. Resource sharing has been taken as the medium for such links [Gerson 76, Gasser 91, Hewitt 91]. In this thesis, it is noted that, in addition to resource sharing, commitments can be linked through other mediums (e.g., commitments themselves). In this thesis this type of linkage of commitments is called direct connection, while resource sharing is called indirect connection. The direct connection may also result in gains/losses in resources but the resource is not the medium for such a connection. For example, accepting a job offer from another company may result in losing part of one's pension plan in the current company. However, it is not the resource, but the terms defined in the pension plan, which he has committed, directly connecting the pension plan with the commitment to the company. Separating the resource sharing and the direct commitment connection might provide better insight into resolving commitment conflicts.

8.2 Limitations and Research Directions

We believe that RECOS is useful for an individual to make better justified and more consistent commitments in a cooperative multi-agent environment. However, as have other models, it also has some limitations which should be considered when the model is applied.

As revealed in the user evaluation, the RECOS model may not be well-suited to deal with request-commitment problems which have alternatives or potential future commitments. This issue should be taken into consideration when applying RECOS to solve real life problems. However, we believe that this problem could be resolved by designing a higher level control

mechanism, which calls RECOS to evaluate each of the alternatives, and manages the comparisons of the evaluation results of the alternatives.

In section 4.2.7, we have discussed that there are potential overlaps between the factor categories. This implies that the user might consider one factor in two or more categories (e.g., reconsidering others' expectations in sentiment evaluation). However, we believe that there are more benefits than drawbacks in separating these factors. As long as the user is aware of this potential problem, its negative effect will be minimized or eliminated. This should be understood in order to maximize the usage of this model.

The RECOS model only provides support in selecting factors to consider and in evaluating such factors for making a commitment. The assistance provided for integration is very limited. As some subjects pointed out during the model evaluation session, a set of integration tools is highly recommended. We agree that this is an important direction for future study.

RECOS is a domain-independent model, and many components are treated as "black boxes" at the current stage. Its real usefulness can only be judged through application systems, which can be used in real life commitment-making. To build application systems, the internal structure of the "black boxes" needs to be represented, and some factors (e.g., sentiment attributes) need to be measured. We foresee that much needs to be done in this direction in order to appreciate the model's full benefits. In addition, to build an application system, the developer not only needs the model but also a set of powerful tools with which to work. Some existing languages (e.g., Prolog) might be used for this purpose, but more suitable and user-friendly tools are desirable.

References

[AlHrAl 73] Alutto, J., Hrebiniak, L., Alonso, R., "On Operationalizing the Concept of Commitment," Social Force, Vol. 51, No. 4, June, 1973, 448-454

[BarOuc 86] Barney, J. B. and Ouchi, W. G. (eds.), *Organizational Economics*, Jossey-Bass, San Francisco, 1986

[Becker 60] Becker, H. S., "Notes of the Concept of Commitment," The American Journal of Sociology, Vol. 66, No. 1, July 1960, 32-40

[BhaCro 90] Bhandaru, N. and Croft, W.B., "An Architecture for Supporting Goal-Based Cooperative Work," in *Multi-User Interfaces and Applications*, Gibbs, S and Verrijn-Stuart, A.A., (eds.), Elsevier Science Publishers B.V. North-Holland, 1990, 337-354

[Bond 90] Bond, A. H., "Commitment: A computational model for organizations of cooperating intelligent agents," *Proceedings of Conference of Office Information Systems*, Cambridge, Massachusetts, April, 25-27, 1990, 21-30

[Borlan 88a] Borland International, *Turbo Prolog: User's Guide*, Scotts Valley, CA., USA, 1988

[Borlan 88b] Borland International, *Turbo Prolog: Reference Guide*, Scotts Valley, CA., USA, 1988

[Borlan 88c] Borland International, *Turbo Prolog: ToolBox*, Scotts Valley, CA., USA, 1988

[Brickm 87] Brickman, P., *Commitment, Conflict, and Caring*, Prentice-Hall, Inc. Englewood Cliffs, New Jersey, 1987

[Bunge 77] Bunge, M., *Treatise on Basic Philosophy:* Vol. 3, Ontology I: The Furniture of the World, Reidel, Boston, 1977

[Bunge 79] Bunge, M., *Treatise on Basic Philosophy:* Vol. 4, Ontology II: A World of Systems, Reidel, Boston, 1977

[BurFla 87] Burns, T. R., and Flam, H., *The Shaping of Social Organization: Social Rule System Theory with Application*, SAGE Publications, London, 1987

[ChaWoo 91] Chang, M. K., Woo, C. C. "SANP: A Communication Level Protocol for Negotiations," Decentralized AI 3 (*Proceedings of the Third European Workshop on Modelling Autonomous Agents in a Multi Agent World*, Kaiserslautern, Germany, August 5-7, 1991), edited by Y. Demazeau and E. Werner, Netherlands: Elsevier Science Publishers B.V., 1992, to appear.

[CohLev 90] Cohen, P.R., and Levesque H., Intention is Choice with Commitment," Artificial Intelligence, Vol. 42, 1990, 213-261

[DeKlee 86] De Klee, J., "An Assumption-Based TMS," Artificial Intelligence, Vol. 28, 1986, 127-162

[Doyle 79] Doyle, J., "A truth maintenance System," Artificial intelligence, Vol. 12, 1979, 495-516

[Fikes 81] Fikes, R. E. "A Commitment-Based Framework for Describing Informal Cooperative Work," *Proceedings of the Third Annual Conference of the Cognitive Science Society*, Berkeley, California, August 19-21, 1981, 17-22

[FisAjz 75] Fishbein, M., and Ajzen, I., *BELIEF, ATTITUDE, INTENTION AND BEHAVIOR: an Introduction to Theory and Research*, Addison-Wesley Publishing Company, 1975

[FlGrHW 88] Flores, F., Graves, M., Hartfield, B., Winograd, T., "Computer Systems and the Design of Organizational Interaction," ACM Transaction on Office Information Systems, Vol. 6, No. 2, April, 1988, 153-172

[FloLud 80] Flores, F., Ludlow, J. J., "Doing and Speaking in the Office," in Decision Support Systems Issues and Challenges G.Fick and R.H. Sprague (eds.), 1980, 95-118,

[Gasser 91] Gasser, L., "Social conceptions of knowledge and action: DAI foundations and open systems semantics," Artificial Intelligence, Vol. 47, 1991, 107-138

[GenNil 87] Genesereth, M. R., and Nilson, N. J., *Logical Foundations of Artificial Intelligence*, Morgan Kaufman, Los Altos, California, 1987

[Gerard 68] Gerard, H.B., "Basic Features of Commitment," in *Theories of Cognitive Consistency A source Book*, Abelson, R.P., et al. (eds), Rand McNally and Company, Chicago, 1968

[Gerson 76] Gerson E. M., "On 'quality of life'," American Sociology Review, Vol. 41, October, 1976, 793-806

[Gove 67] Gove, P.B. (ed.), Webster's Third New World Dictionary of the English Language Unabridged, G&C Merrian Company Publishers, Springfield, Massachusetts, USA, 1967

[HaJaRo 90] Hahn, U., Jarke, M., and Rose, T., "Group Work in Software Projects: Integrated Conceptual Models and Collaboration Tools," in *Multi-User Interfaces and Applications*, Gibbs, S and Verrijn-Stuart, A.A., (eds.), Elsevier Science Publishers B.V., North-Holland, 1990, 83-101

[Hammon 89] Hammond, K. (ed.), *Proceedings of Case-Based Reasoning Workshop*, Pensacola Beach, FL, 1989

[Hewitt 91] Hewitt, C., "Open Information Systems Semantics for Distributed Artificial Intelligence," Artificial Intelligence, Vol. 47, 1991, 79-106

[JanMan 77] Janis, I., Mann, L., *Decision Making, A Psychological Analysis of Conflict, Choice, and Commitment*, The Free Press, New York, 1977

[Johnso 73] Johnson, M. P., "Commitment: A Conceptual Structure and Empirical Application," Sociological Quarterly, Vol, 14, No. 3, Summer, 1973, 395-406

[Kiesle 71] Kiesler, C.A., *The Psychology of Commitment Experiments Linking Behaviour to Belief*, Academic Press, New York and London, 1971

[Kolodn 88] Kolodner, J.L. (ed.), *Proceedings of the 1988 Workshop on Case-Based Reasoning*, Morgan Kaufmann, San Mateo, CA, 1988

[Konoli 85] Konolige, K. "A Computational Theory of Belief Introspection". IJCAI 1985, Vol. 1, Los Angeles, California, 502-508,

[Koo 88] Koo, C. C., "A Commitment-based Communication Model for Distributed Office Environments," *Proceeding of the Conference on Office Information Systems*, Palo Alto, California, March 23-25, 1988, 291-298

[McArth 88] McArthur, G. L., "Reasoning about knowledge and belief: a survey". Computational Intelligence, Vol. 4, No. 3, August, 1988, 223-243

[Macnei 80] Macneil, I.R., *The New Social Contract, An Inquiry into Modern contractual Relations*, Yale University Press, New Haven and London, 1980

[MaGLRR 87] Malone, T. W., Grant, K. R., Lai, K. Y, Rao, R, and Rosenblitt, D., "Semistructured Messages Are Surprisingly Useful for Computer-Supported Coordination," ACM Transactions on Office Information Systems, Vol. 5, No. 2, April 1987, 115-131

[MasJoh 89] Mason, C. L. and Johnson, R. R., "DATMS: A Framework for distributed Assumption Based Reasoning," Distributed Artificial Intelligence, Vol.2, Gasser, L., Huhns, M. N. (eds.), Pitman Publishing, London, 1989, 293-318

[Moore 88] Moore, G., "An Examination of the implementation of Information Technology for End Users: A Diffusion of Innovations Perspective," unpublished Ph.D. Dissertation, University of British Columbia, Vancouver, Canada, 1988

[Mottaz 87] Mottaz, C., "An Analysis of the Relationship between Work Satisfaction and Organizational Commitment," The Sociological Quarterly, Vol. 28, No. 4, 1987, 541-558

[NorSar 91] Noronha, S. J. and Sarahar, V. V. S., "Knowledge Based Approaches for Scheduling Problems: A Survey," IEEE Transactions on Knowledge and Data Engineering, Vol., 3, No. 2, June, 1991, 160-171

[PayEli 76] Payne, B., and Elifson, K., "Commitment: A Comment on Uses of the Concept," Review of Religious Research, Vol. 17, No. 3, Spring, 1976, 209-215

[Pruitt 81] Pruitt, D. G., *Negotiation Behaviour*, Academic Press, Inc., 1981, New York

[[Sayeed 89] Sayeed, Omer-Bin, "*Perception of Organizational Commitment: Preliminary Findings and Scale Construction*," Indian Journal of Social Work, Vol. 50, No. 3, July, 1989, 317-328

[Simon 57] Simon, H.A., *Administrative Behaviour: A Study of Decision-Making Processes in Administrative Organization*, The Macmillan Company, New York, 1977

[SprCar 82] Sprague, R. H. Jr. and Carlson, E. D., *Building Effective Decision Support Systems*, Prentice-Hall, Inc., Englewood Cliffs, N.J., USA, 1982

[VoKaDL 90] VoB, A., Karbach, W., Drouven, U., Lorek, D., "Competence Assessment in Configuration Tasks," Ai Communications, Vol. 3, No. 3, Sept, 1990, 107-114

[WanWoo 91] Wand, Y., and Woo, C. C., "An Approach to Formalizing Organizational Open Systems Concepts," Proceedings of the (ACM & IEEE) Conference on Organizational Computing Systems, Atlanta, Georgia, November 5-8, 1991, 141-146

Appendix

This appendix includes figures describing the detailed structure of the reasoning components contained in Figure 1. In all these figures, the meaning of each symbol is as follows: an oval represents a process in which factor evaluation or other reasoning is done; a vertical rectangle represents the user or another agent; a vertical rectangle with corners rounded represents a knowledge base; an arrow between ovals or between an oval and a box depicts the working direction, with the information flowing from the starting oval/box to the end one; an arrow between an oval and a knowledge base means that the process retrieves a specified item from the knowledge base; and a double arrow means there are some information exchanges between the involved parties.

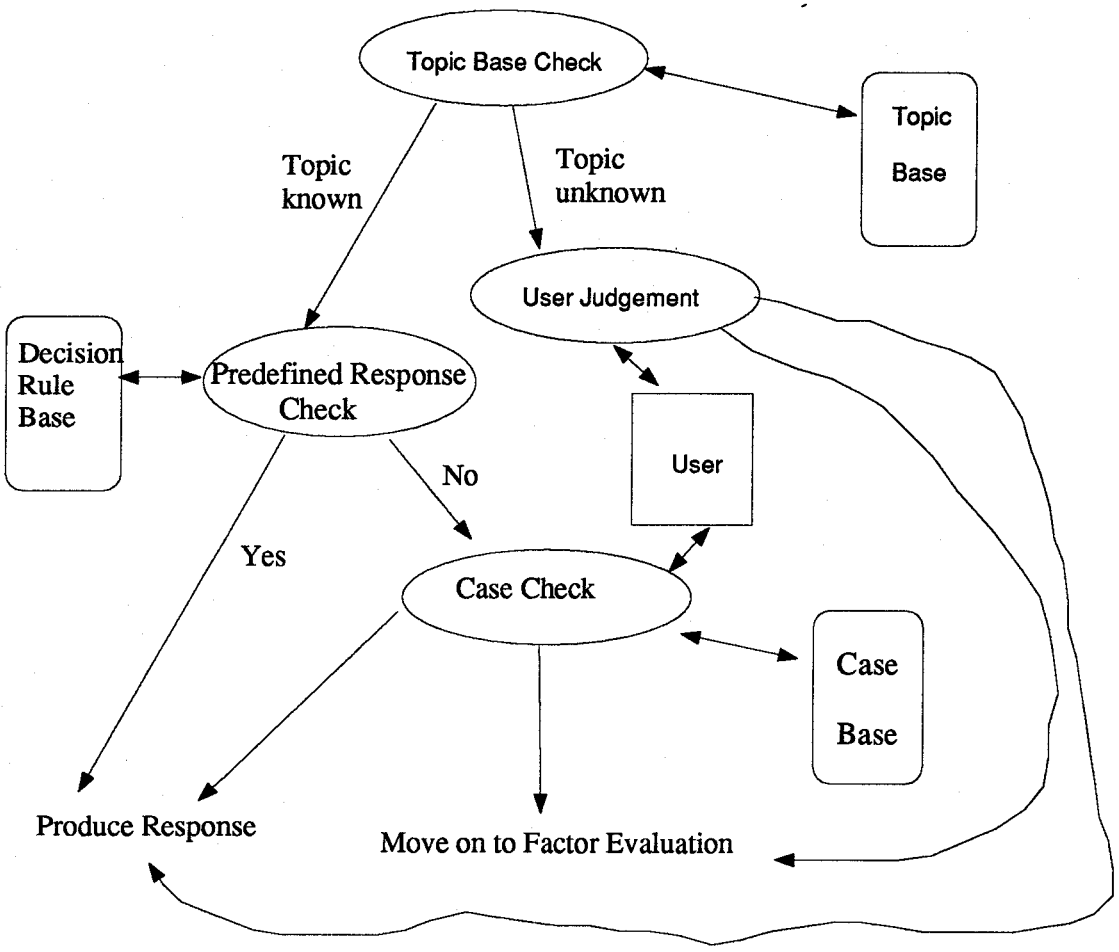

Figure A1: The reasoning process of the "Preprocessing Module " in Figure 1.

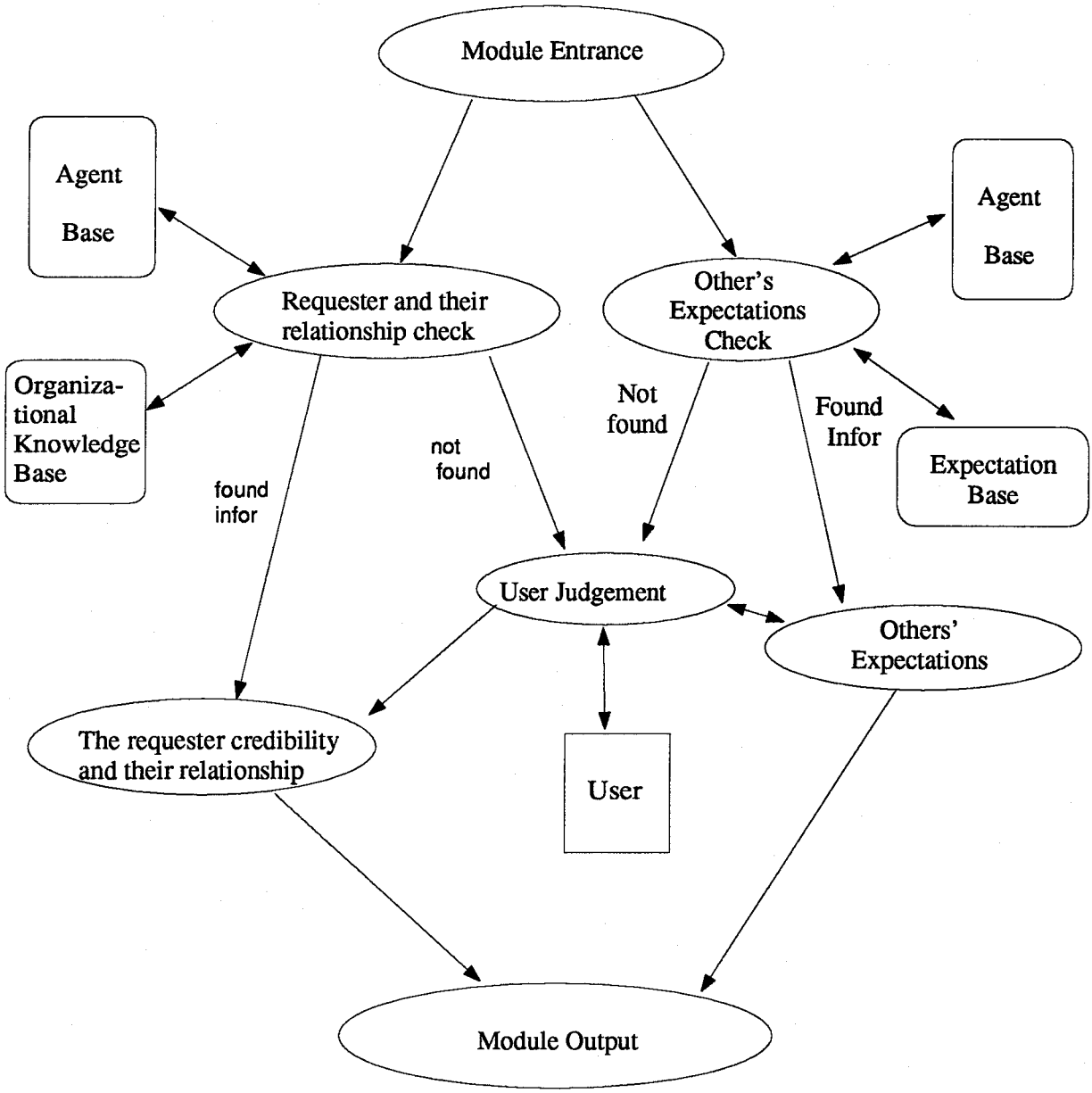

Figure A2. The reasoning process of the "Requester, Inter-agent relationship, and Other's Expectations" in Figure1

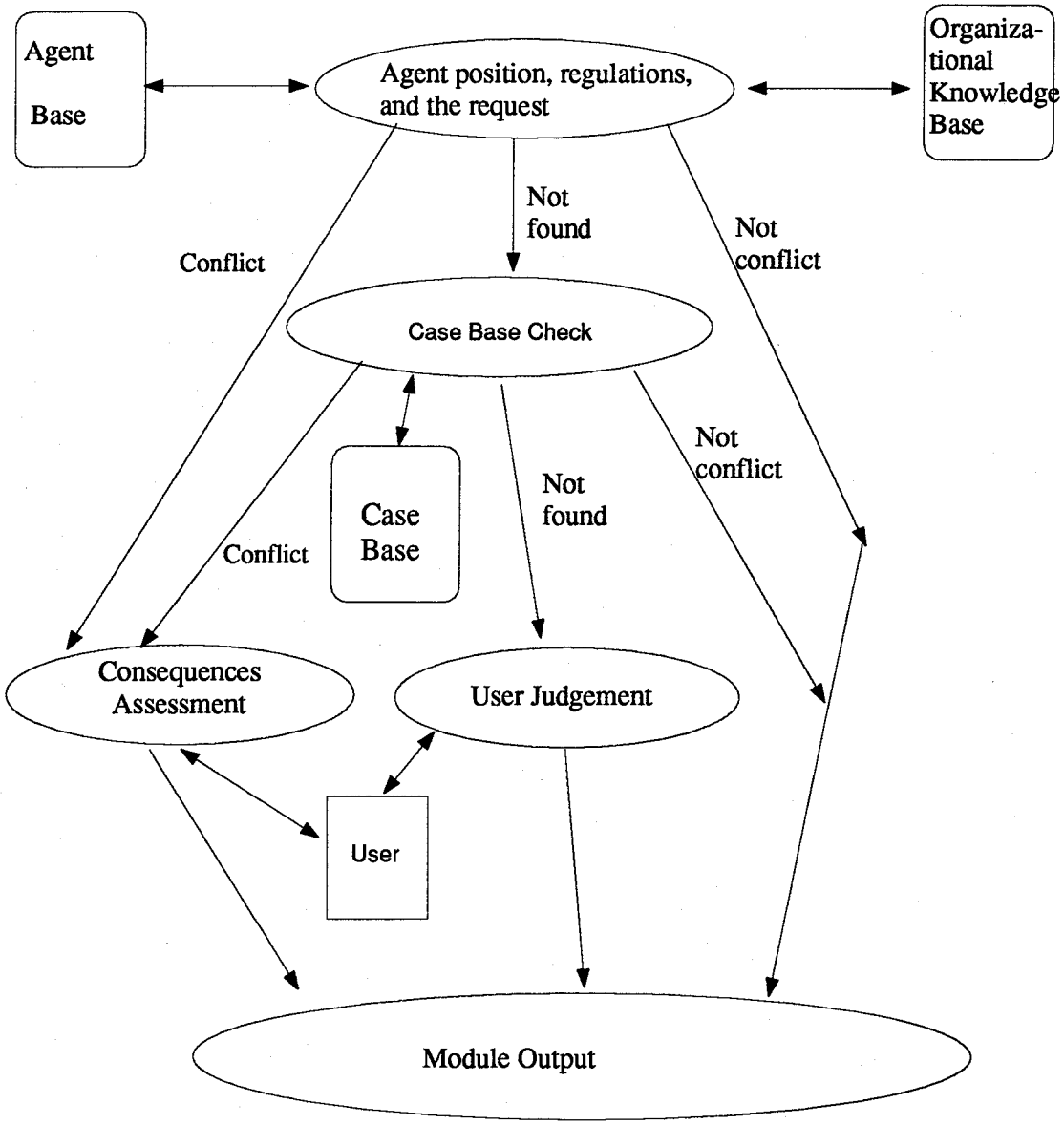

Figure A3: The reasoning process of "Regulation Assessment" in Figure 1.

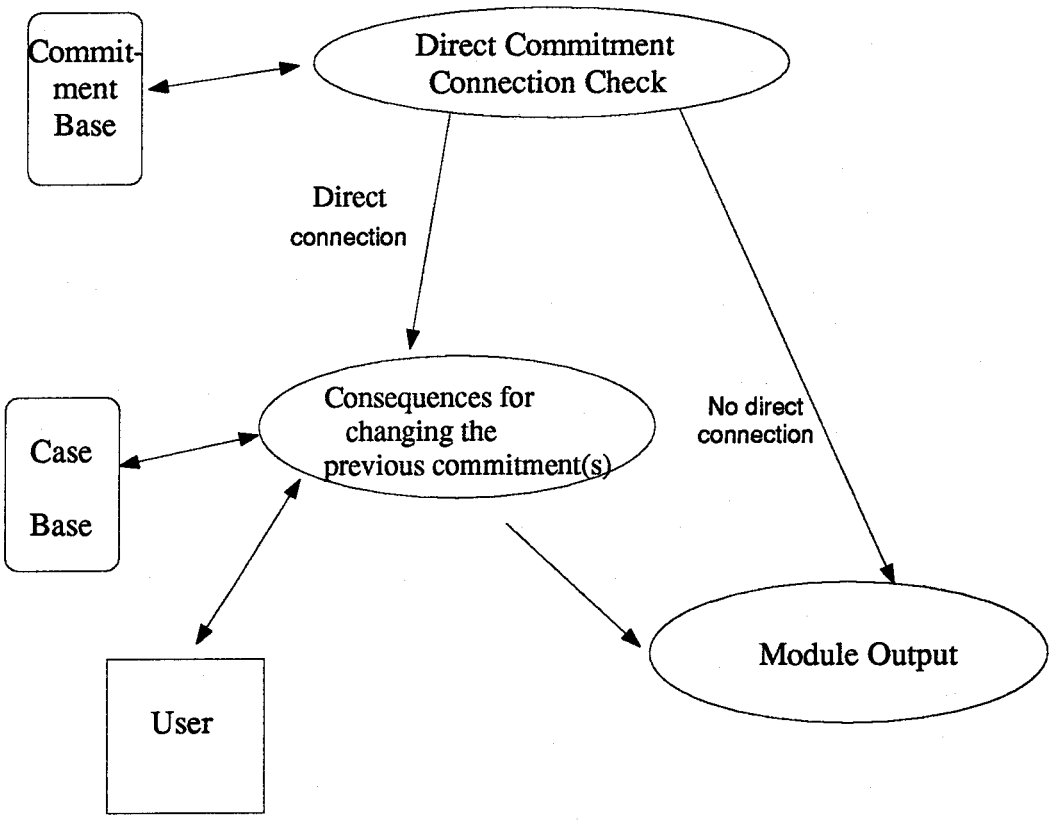

Figure A4: The reasoning process of "Commitment Consistence" in Figure 1.

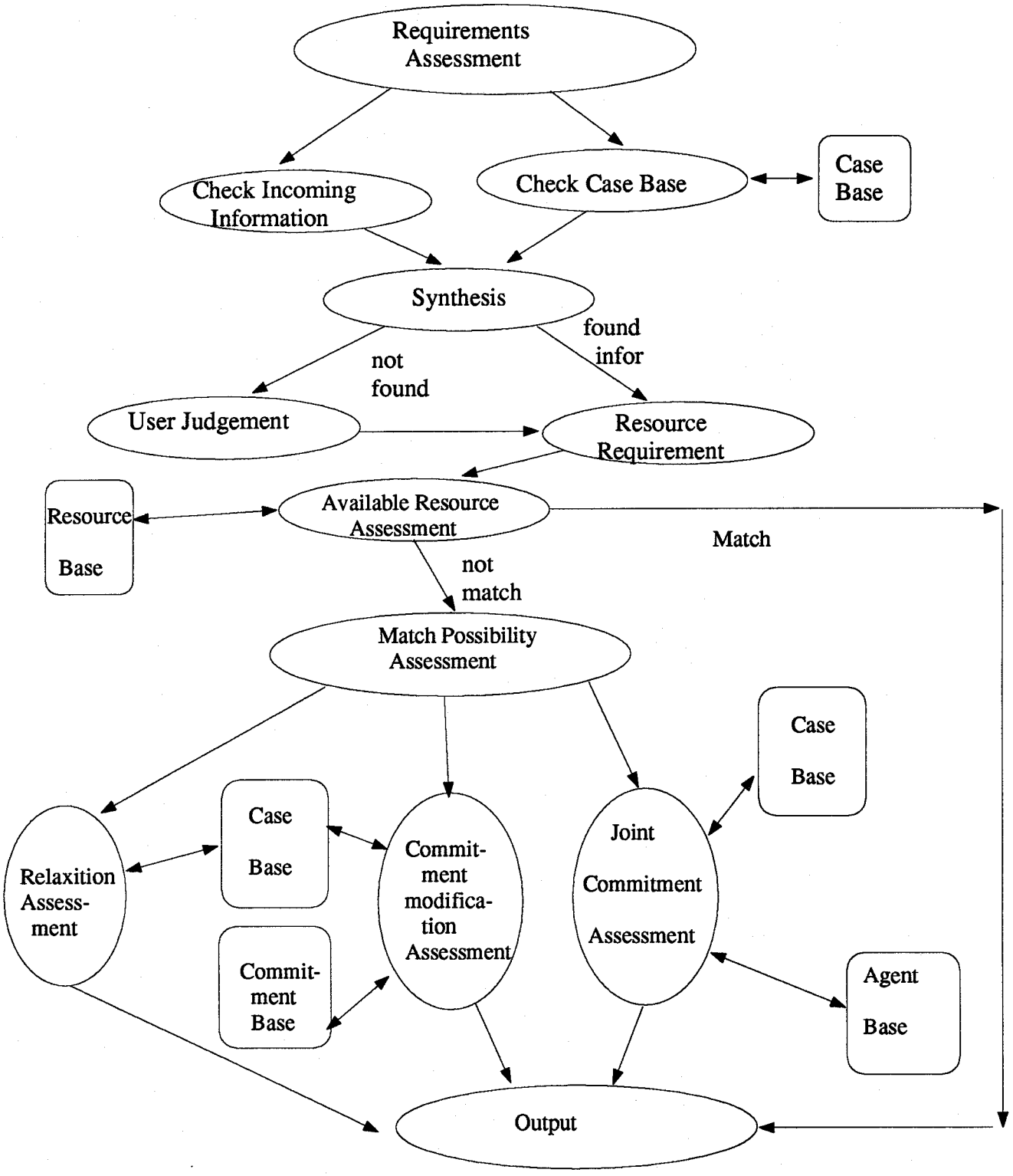

Figure A5: The reasoning process of " Competence Assessment" in Figure 1.

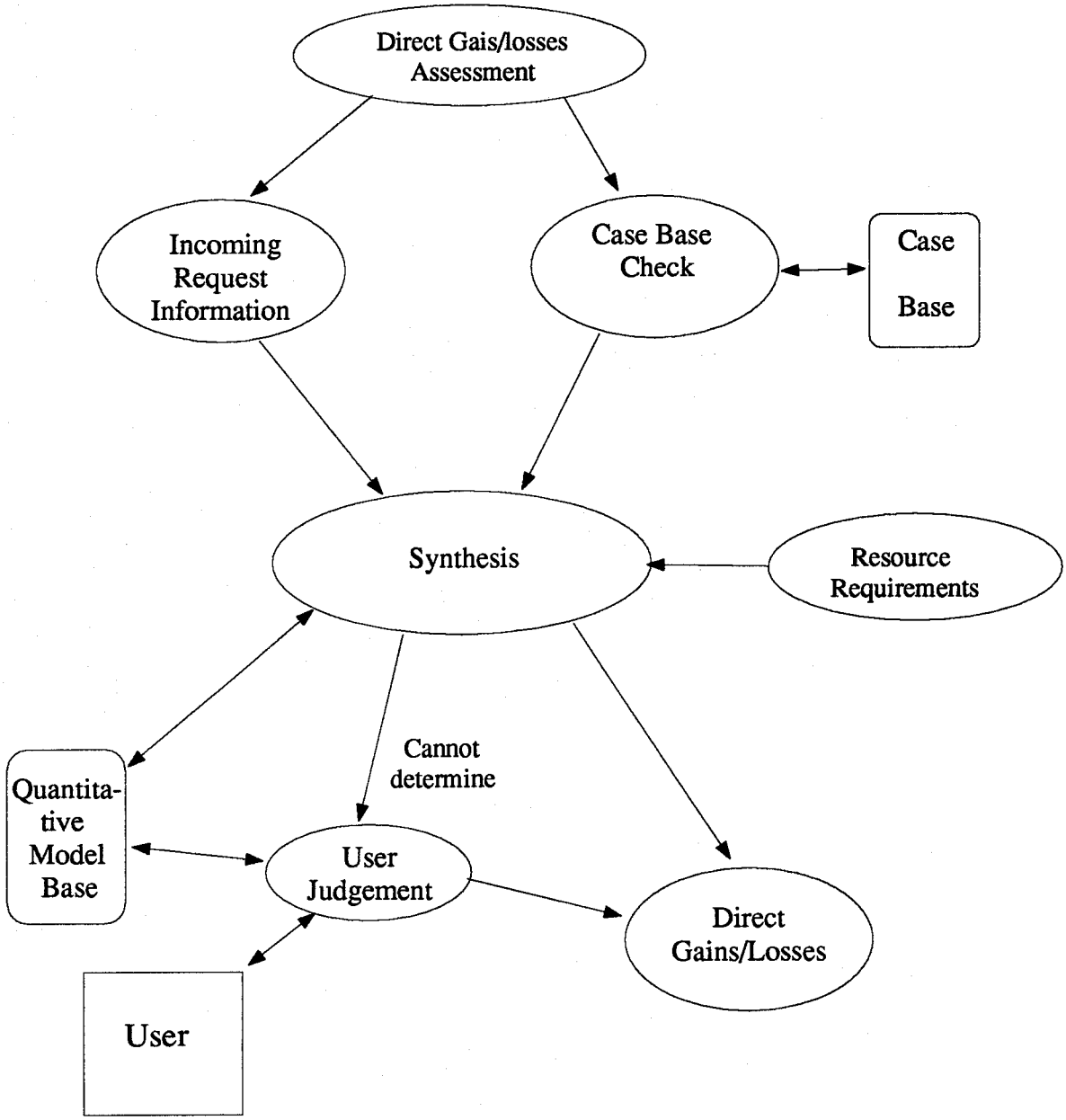

Figure A6: The reasoning process of "Direct Gains/Losses" in Figure 1.