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## **Abstract**

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## **Keywords**

case-based reasoning, electronic commerce, fraud, multi-agent systems, security of data

## **Disciplines**

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# Experience Based Reasoning for Recognising Fraud and Deception

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## Abstract

*Fraud, deception and their recognition have received increasing attention in multiagent systems (MAS), e-commerce, and agent societies. However, little attention has been given to the theoretical foundation for fraud and deception from a logical viewpoint. This paper will fill this gap by arguing that experience-based reasoning (EBR) is a logical foundation for recognizing fraud and deception. It provides a logical analysis of deception, which classifies recognition of deception into knowledge-based deception recognition, inference-based deception recognition, and hybrid deception recognition. It will examine the relationship between EBR and fraud as well as deception. It uses EBR to recognize fraud and deception in e-commerce and MAS. The proposed approach will facilitate research and development of recognition of fraud and deception in e-commerce.*

**Keywords:** Fraud, deception, experience-based reasoning, multiagent system, e-commerce.

## 1. Introduction

Fraud and deception are ubiquitous in human life and society. Detecting and recognizing fraud and deception has been always a big issue for philosophy, business, commerce, and military operation over more than two thousand years [17]. Recognizing fraud and deception in human communication, exchange and relations [25] have also received increasing attention in artificial intelligence [23], MAS [13], e-commerce [18], and agent societies [14][26] since the end of last century. For example, Wheeler and Aitken proposed multiple algorithms for fraud detection in the credit approval process based on case based reasoning [23]. Schillo, Frank and Rocatsos proposed a formalization and an algorithm for dealing with deception in a MAS, where agents may find themselves confronted with fraud

and deception [13]. Castelfranchi and Tan analyzed the role of deception in interaction between agents in virtual socie-ties [4]. Furthermore, many AI models, BDI models, and cognitive models of fraud and deception and approaches for detecting deception have been developed in the last few years [5][25][27]. For example, artificial neural network are widely used in fraud detection by tax offices and credit card companies [28]. However, little attention has been given to the theoretical foundation for fraud and deception and their recognition from a logical viewpoint. This paper will fill this gap with arguing that experience-based reasoning (EBR) is a logical foundation for recognizing fraud and deception.

EBR is a reasoning paradigm based on logical arguments [2]. EBR as a technology has been used in many applications [16][18]. Taking into account research and development of case-based reasoning (CBR), Sun and Finnie [18][19] proposed eight different inference rules for EBR from a logical viewpoint, which cover all possibilities of EBR, in order to move EBR towards a firm theoretical foundation. However, what is the relationship between EBR and fraud as well as deception? Can we use EBR to recognize fraud and deception in e-commerce and MAS? These questions are still open, although their answers will improve our understanding of EBR, fraud and deception in e-commerce and MAS. This paper will also provide some answers to these questions.

In what follows, our attention will be focused primarily on fraud and deception, EBR and their recognition using EBR. Although our approach might be of significance in areas such as e-commerce, decision processes, business negotiation, agent societies, MAS, and hybrid intelligent systems, we shall make no attempt in this paper to discuss its applications in these areas. Because this work was motivated when we attempted to develop logical EBR and its applications to detecting and recognising fraud and deception in e-commerce and MASs [24], we will use e-commerce and MASs as scenarios, if required.

The rest of this paper is organized as follows: Section 2. examines fraud and deception, which are classified into three different categories: knowledge-based fraud and deception, inference-based fraud and deception, and hybrid fraud and deception. Section 3. looks at experience based reasoning. Section 4. reviews inference rules for EBR from a logical viewpoint. Section 5. examines the recognition of fraud and deception based on EBR. Section 6. ends this paper with some concluding remarks.

## 2. Fraud and Deception

This section will examine what fraud and deception are, where fraud and deception come from, and the classification of fraud and deception.

### 2.1 What are Fraud and Deception

Although fraud and deception have been received increasing attention in artificial intelligence [23], multiagent systems (MAS) [13], e-commerce [18], and agent societies [14][26] since the end of last century, there is no consensus in definitions of fraud and deception. In what follows, we like to use the following general definitions for them, which are taken from a dictionary<sup>1</sup>.

*Fraud* is the crime of obtaining money by deceiving people; a person or thing that is not what is claimed.

*Deception* is an act of hiding the truth, especially, to get an advantage.

In business and other social activities, fraud depends on deception, while deception is realized through hiding the truth. Further, the aim of both fraud and deception is to get advantage. Therefore, in what follows, we only use deception instead of fraud and deception, if necessary.

There are many different types of deception in human history, in particular, in wars, in politics or in business [7]. One of the well known military books written by the Chinese ancient military scientist Sun Tzu over 2000 years ago is "the art of War" [15]. In this book there are many deceptions (rather than tactics) which are appropriate to the corresponding military operations. Furthermore, everybody has at least one experience in deceiving another person or being deceived by someone [17]. Therefore, we can assert that deception is ubiquitous in human life and society.

### 2.2 Fraud and Deception in Artificial Societies

With the development of the Internet, we find ourselves in hybrid artificial societies, where, real world assumptions and the whole range of possible behaviors including fraud and deception must be taken into account [13]. Therefore, it

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1. Cambridge International Dictionary of English, Cambridge University Press, 1995.

is also essentially important for us to deal with deception and fraud in such virtual societies.

Further, people will continue to deceive each other in e-commerce or virtual community just as they do in traditional social interaction [4]. The Internet techniques provide new opportunities and ways to deceive, because intelligent agents will also participate in fraud and deception, and agents are and will be designed, selected or trained to deceive and perform fraud, and people will be also deceived by intelligent agents. Therefore, from an e-commerce viewpoint, there are three different kinds of fraud and deception in hybrid artificial societies: fraud and deception between humans (via computers), fraud and deception between humans and intelligent agents, fraud and deception between agents in multiagent societies such as multiagent e-commerce [18].

Now we have to ask: where is a deception from? In order to answer this question, we would like to first discuss knowledge-based systems and logical systems.

### 2.3 Knowledge Based Systems and Logical Systems

Knowledge-based systems (KBS)<sup>2</sup> have been one of the most important fields in AI since the 1970s [11]. A KBS mainly consists of a knowledge base (KB) and an inference engine (IE) [11]. A KBS can be considered as a computerized logical system [20], because a formal logical system largely consists of two parts: an axiom system and an inference system [21]<sup>3</sup>, as shown in Fig. 1. The axiom system consists of a set of axiom schemes, while the inference system consists of a set of inference rules [12]. The simplest inference system is a singleton, which consists only of *modus ponens* (or *modus tollens*). In other words, *modus ponens* (or *modus tollens*) and an axiom system constitutes a formal logical system for deduction [12]. Therefore, the computerized counterpart of the axiom system is the knowledge base (KB), while the computerized counterpart of the inference system is the IE. The KB consists of predicate calculus facts and rules about the domain in consideration, while the IE is an inference mechanism consisting of all the processes that manipulate the KB to deduce knowledge requested by the knowledge user- resolution, or forward or backward chaining, for example [11] (p. 282).

From Fig. 1, we can see that a KBS has a sound theoretical foundation. Furthermore, if we consider a logical system as a micro-world, then any change in either the axiom system or the inference system of the logical system will change the micro-world into another micro-world. Corre-

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2. We mainly focus on rule-based expert systems.

3. This comparison may seem to be simplified to some readers. More generally, a formal logic consists principally of a language set  $L$  and an inference rule set  $I$  [17].

spondingly, any change of either axioms or inference rules will lead to a critical change of the formal logical system. Because an expert system is an attempt to automate a human expert, we can assert that any change of either knowledge or reasoning methods of a human will lead to changes in his behaviour or action.

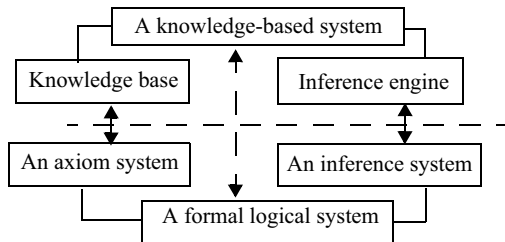


Fig. 1. Relationship between KBS and logical systems.

## 2.4 A Logical Analysis of Deception

In what follows, we assume that  $P$  is an agent<sup>1</sup> and  $Q$  is another agent.  $P$  has knowledge set  $K_p$ , reasoning methods set  $R_p$ ;  $Q$  has knowledge set  $K_Q$ , reasoning methods set  $R_Q$ . Therefore, under the same environment, the behaviour of  $P$  and  $Q$  will be decided by  $(K_p, R_p)$  and  $(K_Q, R_Q)$  from a knowledge-based viewpoint (see Section 2.3). Now we will turn to the question: where is a deception from?

In a most general case, one of the essential conditions for performing fraud or deception is that agent  $P$  and  $Q$  have difference in either knowledge or inference methods [17]. In other words, the necessary condition for performing deception, either agent  $P$  to agent  $Q$  or agent  $Q$  to agent  $P$  is that either  $K_p \neq K_Q$  or  $R_p \neq R_Q$ . Therefore, there are three different possibilities that lead to a deception between agent  $P$  and agent  $Q$ :

1.  $K_p \neq K_Q$  and  $R_p = R_Q$
2.  $K_p = K_Q$  and  $R_p \neq R_Q$
3.  $K_p \neq K_Q$  and  $R_p \neq R_Q$

More specifically, the first possibility is that a deception comes from different background knowledge but same reasoning rules of the two agents  $P$  and  $Q$ . For example, agent  $P$  has a knowledge base:  $A$  and If  $A$  then  $B$ , and uses *modus ponens*, which is a well-known inference rule, but agent  $Q$  has the knowledge base:  $A$  and If  $A$  then  $C$ , and also one uses *modus ponens*, then a deception may occur. The

1. In traditional society, an agent stands for a human while it stands for an intelligent agent in virtual society or multiagent e-commerce.

deception resulting from the first possibility is called *knowledge-based deception*, because the deception comes from the difference between knowledge of agent  $P$  and that of agent  $Q$ .

The second possibility is that a deception comes from same background knowledge, using different inference rule(s), i.e.  $P$  has knowledge  $K_p$  and at the same time  $Q$  has same knowledge  $K_Q = K_p$ , whereas they use different inference rules, e.g.  $P$  uses *modus ponens*:  $A, A \rightarrow B \Rightarrow B$ , while  $Q$  uses *modus ponens with trick*:  $A, A \rightarrow B \Rightarrow \neg B$  [18]. Thus the disjoint sum  $R_p + R_Q \neq \emptyset$ , which leads to a deception, because  $P$  thought that  $Q$  would obtain the same conclusion as what he obtained, but  $Q$  would not. The deception resulting from the second possibility is called *inference-based deception*, because the deception comes from the difference between reasoning methods of agent  $P$  and that of agent  $Q$ .

The third possibility is that a deception comes from both different knowledge and different inference rules between  $P$  and  $Q$ . The deception resulting from the third possibility is called *hybrid deception*. It is very common for two agents  $P$  and  $Q$  in the real world to have different knowledge and different reasoning methods. Therefore, hybrid deception is a common behaviour in all kinds of deception behaviours in the real world. However, in MASs, e-commerce, and virtual society, it is not difficult for us to find two agents  $P$  and  $Q$  having the same knowledge and same reasoning methods, in particular from a knowledge-based viewpoint, because such agents depend on the MASs technology in a period. Therefore, it is still significant to examine hybrid deception in such systems.

Based on the above discussion, we see that classification of deception into knowledge based deception, inference based deception and hybrid deception requires corresponding recognition methods, which will be examined later in this paper.

It should be noted that inference-based deception behaviour of agent  $P$  is a reasoning paradigm which can not recognised by agent  $Q$  at a special time and under a special circumstance. The deception of  $P$  and its corresponding recognition of  $Q$  usually is based on past experience. Therefore, in what follows, we turn to experience based reasoning.

## 3. Experience Based Reasoning

Experience based reasoning (EBR), as a special kind of knowledge-based reasoning (KBR), is drawing increasing attention [1]. EBR is a reasoning paradigm using prior experiences to solve problems [18]. However, EBR is still at an early stage. Bergmann [1] has proposed using CBR as a key technique in experience management (EM). CBR is a

special kind of experience based reasoning (EBR) [29][18]. But there are many different kinds of EBR, which correspond to countless different experiences in our culture and social life, which CBR can not cover. In fact, some EBR paradigms, which have not been familiarized to ordinary people, are a real foundation for inference-based deception and hybrid deception. Therefore, it is significant to examine all possible EBR paradigms, at least from a logical viewpoint. In order to understand this point, let us first look at how a human performs EBR in his social activities with the following example [21]:

Peter Hagen is a distinguished Professor of Business and Commerce at the University of Trickland<sup>1</sup>. He has participated in many international conferences and visited many different countries for academic travel. He teaches his student *logistics* using *modus ponens* and *modus tollens* [8][18], while he explains some social phenomena using abductive reasoning [22]. When he participates in business negotiation with his competition, he likes to use *modus ponens with trick*<sup>2</sup> and *modus tollens with trick* [16]. He also likes to conduct some investment, in which he likes to use *inverse modus ponens* [19]. When asked for investment advice by people he does not trust, he uses *inverse modus ponens with trick* and *abduction with trick* [18].

From this example, we can see that:

- Any human activities usually involve application of many reasoning paradigms such as abduction, deduction, and reasoning with trick
- Any person has to perform many different reasoning paradigms in order to cope with different social situations or occasions
- A person uses a specific reasoning paradigm depending on his experience in different social occasions.

Therefore, only one reasoning paradigm like CBR, which only simulates an experience principle: "similar problems have similar solutions" [1], is insufficient to model or simulate all experiences or all kinds of EBR, as shown in Fig. 2. This is also one of the reasons why expert systems have

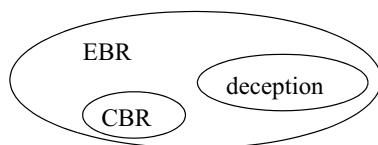


Fig. 2. CBR, EBR and deception.

not reached the goal of researchers of expert systems [18]. Frankly speaking, one significant contribution of CBR research and development is that it points out the importance of experience and EBR, and provides some methodologies such as case reuse and case retention which can be

1. Which is an invented name.  
2. We use trick and deception interchangeably from now on.

used in experience reuse and experience retention in EBR and EM.

It should be noted that any EBR is based on certain inference rules, just as the basis for any reasoning paradigm discussed in AI and mathematical logic is inference rules (also see Section 2.3). Therefore, it is necessary to discuss inference rules for EBR in order to understand the relationship of EBR and deception.

#### 4. Inference Rules for EBR

From a logic viewpoint, there are eight basic inference rules for performing EBR [18][19], which are summarized in Table 1, and cover all possible EBRs, and constitute the fundamentals for all EBR paradigms [16][18][19]. The eight inference rules are listed in the first row, and their corresponding general forms are shown in the second row respectively. Because four of them, *modus ponens* (MP), *modus tollens* (MT), *abduction*, and *modus ponens with trick* (MPT) are well-known in AI and computer sciences [11][18], we do not go into them any more in this section, and focus on reviewing the other four inference rules in some detail. First of all, we illustrate *modus tollens with trick* (MTT) with an example<sup>3</sup>. We have the knowledge in the knowledge base (KB):

1. If Klaus is human, then Klaus is mortal
2. Klaus is immortal.

What we wish is to prove "Klaus is human". In order to do so, let

- $A \rightarrow B$ : If Klaus is human, then Klaus is mortal
- $A$ : Klaus is human
- $B$ : Klaus is mortal.

Therefore, we have  $A$ : Klaus is human, based on MTT, and the knowledge in the KB (note that  $\neg B$ : Klaus is not mortal). From this example, we can see that *modus tollens with trick* is a kind of EBR.

*Abduction with trick* (AT) can be considered as a "dual" form of abduction, which is also the summary of a kind of EBR [19]. Abduction can be used to explain that the symptoms of the patients result from specific diseases, while abduction with trick can be used to exclude some possibilities of the diseases of the patient [20][21]. Therefore, abduction with trick is an important complementary part for performing system diagnosis and medical diagnosis based on abduction.

*Inverse modus ponens* (IMP) is also a rule of inference in EBR. The "inverse" in the definition is motivated by the fact that the "inverse" is defined in mathematical logic: "if  $\neg p$  then  $\neg q$ ", provided that if  $p$  then  $q$  is given [8]. Based

3. Because of space limit, we do not introduce any other example in this paper from now on.

Table 1: Experience-based reasoning: Eight inference rules.

MP	MT	abduction	MTT	AT	MPT	IMP	IMPT
$A$	$\neg B$	$B$	$\neg B$	$B$	$A$	$\neg A$	$\neg A$
$\frac{A \rightarrow B}{\therefore B}$	$\frac{A \rightarrow B}{\therefore \neg A}$	$\frac{A \rightarrow B}{\therefore A}$	$\frac{A \rightarrow B}{\therefore A}$	$\frac{A \rightarrow B}{\therefore \neg A}$	$\frac{A \rightarrow B}{\therefore \neg B}$	$\frac{A \rightarrow B}{\therefore \neg B}$	$\frac{A \rightarrow B}{\therefore B}$

on this definition, the inverse of  $A \rightarrow B$  is  $\neg A \rightarrow \neg B$ , and then from  $\neg A$ ,  $\neg A \rightarrow \neg B$  we have  $\neg B$  using modus ponens. Because  $A \rightarrow B$  and  $\neg A \rightarrow \neg B$  are not logically equivalent, the argument based on *inverse modus ponens* is not valid in mathematical logic and mathematics. However, the EBR based on *inverse modus ponens* is a kind of common sense reasoning, because there are many cases that follow *inverse modus ponens*. For example, if John has enough money, then John will fly to Tianjin, China. Now John does not have sufficient money, then we can conclude that John will not fly to Tianjin.

It should be noted that inverse modus ponens has received attention from some researchers [8] (p. 36). However, the researchers consider this inference rule as the source of fallacies in the reasoning, while we argue that it is a basic inference rule for EBR [19].

The last inference rule for EBR is *inverse modus ponens with trick* (IMPT). The difference between IMPT and inverse modus ponens is again "with trick", this is because the reasoning performer tries to use the trick of "make a feint to the east and attack in the west"; that is, he gets B rather than  $\neg B$  in the *inverse modus ponens*.

So far, we have reviewed eight different inference rules for EBR (see Table 1) from a classic logical viewpoint, four of them have been thoroughly used in computer science, mathematics, mathematical logic, philosophy and other sciences. The rest have not been appeared in any publications except [19][21], to our knowledge. However, they are all the abstraction and summary of experience or EBR in real world problems. Therefore, any research and development of each listed inference model is significant for understanding of intelligence, logic, fraud and deception.

From a theoretical viewpoint, the current AI models, and other computational models of fraud and deception are basically based on the first four inference rules because they are the basis for mathematics, and logic and then for AI and other sciences.

The remaining four inference rules "with trick" such as MTT, AT, IMP and IMPT are non-traditional inference rules, which have not been studied in mathematics, logic and AI. However, they are really abstractions of some EBR, although few have tried to formalize them. The above formalization for them is a first attempt in this direction, to our knowledge. The "with trick" is only an explanation for such models. One can give other explanations such as fraud or deception for them, depending on his/her indi-

vidual preference. For example, agent  $P$  has knowledge set  $K_p$ , reasoning methods set  $R_p$ ,  $Q$  has knowledge set  $K_Q$ , reasoning methods set  $R_Q$ , even if  $K_p = K_Q$ , the agent  $Q$  can still deceive agent  $P$  if agent  $Q$  uses either of the above four inference rules with trick, because agent  $P$  still does not know them. Therefore, fraud and deception behaviors can be considered as special EBRs.

## 5. Recognising Fraud and Deception

There are many paper-based techniques for detecting and recognising fraud and deception in traditional business activities [4]. However it is difficult for these techniques to be adequate in e-commerce or virtual society, where you or agents usually never meet your trade partner physically and where messages can be read or copied a million times without leaving any trace.

According to the classification of deception in Section 2.4, we classify recognition of fraud and deception into three categories:

- Recognition of knowledge-based fraud and deception
- Recognition of inference-based fraud and deception
- Recognition of hybrid fraud and deception.

Because of space limitations, we can only examine the second category, in what follows.

Assume that agent  $P$  and agent  $Q$  are two agents in a multiagent system.  $P$  has knowledge set  $K_p$ , reasoning methods set  $R_p$ ,  $Q$  has knowledge set  $K_Q$ , reasoning methods set  $R_Q$ , and  $K_p = K_Q$ ,  $Q$  might deceive agent  $P$  if  $R_p \neq R_Q$ , vice versa. Therefore, in this case, recognition of inference-based fraud and deception is equivalent to the activities including classification, identification, detection, matching, and recognition of inference rules that  $P$  and  $Q$  use, and possess  $R_p \neq R_Q$ . In Section 4. we proposed eight different inference rules that cover all possibilities of EBRs from a logical viewpoint. Therefore, the classification for potential fraud and deception is that if  $Q$  uses the first inference rule in Table 1, then  $P$  can only use other seven inference rules, in order to deceive  $Q$ , therefore,  $P$  has  $C_8^2 = 28$  potential inference-based deceptions. In other words,  $Q$  must identify, detect, and recognise all these

inference-based deceptions, in order to prevent any potential inference-based deception using established rule-based patterns [3] in the knowledge base of the multiagent system for recognising fraud and deception.

## 6. Concluding Remarks

This paper argued that experience-based reasoning is a logical foundation for recognising fraud and deception. Further, it examined the relationship between EBR and fraud as well as deception. It used EBR to recognize fraud and deception, and looked at inference based deception recognition. The logical analysis of deception leads to classification of recognition of deception into knowledge-based deception recognition, inference-based deception recognition, and hybrid deception recognition. The proposed approach will facilitate research and development of recognition of fraud and deception in e-commerce and MAS.

In future work, we will use the proposed methodology for recognition of fraud and deception in e-commerce, which is one of our current research projects. In this project, we will classify fraud and deception in e-commerce in such categories that any fraud or deception behavior can be easily recognised. We will also propose a multi-agent architecture for recognising fraud and deception, and realize a MAS prototype based on the logical approach and similarity-based approach to EBR [21], which will be a platform for applying EBR in recognition of fraud and deception in e-commerce.

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