Whitestein Series in Software Agent Technologies and Autonomic Computing

Series Editors:
Marius Walliser
Stefan Brantschen
Monique Calisti
Marc Herbstritt

This series reports new developments in agent-based software technologies and agent-oriented software engineering methodologies, with particular emphasis on applications in the area of autonomic computing & communications.

The spectrum of the series includes research monographs, high quality notes resulting from research and industrial projects, outstanding Ph.D. theses, and the proceedings of carefully selected conferences. The series is targeted at promoting advanced research and facilitating know-how transfer to industrial use.

About Whitestein Technologies

Whitestein Technologies is a leading innovator in the area of software agent technologies and autonomic computing & communications. Whitestein Technologies' offering includes advanced products, solutions, and services for various applications and industries, as well as a comprehensive middleware for the development and operation of autonomous, self-managing, and self-organizing systems and networks.
Whitestein Technologies' customers and partners include innovative global enterprises, service providers, and system integrators, as well as universities, technology labs, and other research institutions.

www.whitestein.com
Huiye Ma
Ho-fung Leung

Bidding Strategies in Agent-Based Continuous Double Auctions
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>ix</td>
</tr>
<tr>
<td><strong>1 Introduction</strong></td>
<td>1</td>
</tr>
<tr>
<td>1.1 Agent-Based Auctions in Electronic Commerce</td>
<td>1</td>
</tr>
<tr>
<td>1.1.1 Auctions in Electronic Commerce</td>
<td>1</td>
</tr>
<tr>
<td>1.1.2 Agent-Based Auctions in Electronic Commerce</td>
<td>2</td>
</tr>
<tr>
<td>1.1.3 Motivations of this Work</td>
<td>3</td>
</tr>
<tr>
<td>1.2 Research Aims</td>
<td>4</td>
</tr>
<tr>
<td>1.3 Research Contributions</td>
<td>5</td>
</tr>
<tr>
<td>1.4 Book Structure</td>
<td>6</td>
</tr>
<tr>
<td><strong>2 Agent-Based CDAs and Bidding Strategies</strong></td>
<td>9</td>
</tr>
<tr>
<td>2.1 Agent-Based Continuous Double Auctions</td>
<td>9</td>
</tr>
<tr>
<td>2.2 Continuous Double Auction Mechanisms</td>
<td>11</td>
</tr>
<tr>
<td>2.2.1 Basic CDA Mechanisms</td>
<td>11</td>
</tr>
<tr>
<td>2.2.2 Variants of Basic CDA Mechanisms</td>
<td>11</td>
</tr>
<tr>
<td>2.3 Bidding Strategies for Agents in CDAs</td>
<td>13</td>
</tr>
<tr>
<td>2.3.1 Zero Intelligence Bidding Strategy</td>
<td>15</td>
</tr>
<tr>
<td>2.3.2 ZIP Bidding Strategy</td>
<td>15</td>
</tr>
<tr>
<td>2.3.3 CP Bidding Strategy</td>
<td>17</td>
</tr>
<tr>
<td>2.3.4 GD Bidding Strategy</td>
<td>18</td>
</tr>
<tr>
<td>2.3.5 A-FL Bidding Strategy</td>
<td>19</td>
</tr>
<tr>
<td>2.3.6 Other Bidding Strategies</td>
<td>22</td>
</tr>
<tr>
<td>2.3.7 Discussion</td>
<td>23</td>
</tr>
<tr>
<td>2.4 Evaluation Criteria of Bidding Strategies</td>
<td>24</td>
</tr>
<tr>
<td>2.5 Approaches for Analyzing Bidding Strategies</td>
<td>25</td>
</tr>
<tr>
<td>2.5.1 Experimental Approaches</td>
<td>25</td>
</tr>
<tr>
<td>2.5.2 Game Theoretic Analysis Approaches</td>
<td>26</td>
</tr>
<tr>
<td>2.5.3 Empirical Game Theoretic Analysis Approaches</td>
<td>26</td>
</tr>
<tr>
<td>2.5.4 Evolutionary Approaches</td>
<td>27</td>
</tr>
<tr>
<td>2.5.5 Approaches Adopted in this Book</td>
<td>27</td>
</tr>
</tbody>
</table>
3 The Adaptive Attitude Bidding Strategy 29
  3.1 Eagerness ........................................ 29
    3.1.1 Eagerness in Agent Interactions ................. 29
    3.1.2 Eagerness Function for Agents in CDAs ............ 30
  3.2 Bidding Strategies Based on Eagerness ................ 32
    3.2.1 The Bidding Strategy for Sellers ................ 32
    3.2.2 The Bidding Strategy for Buyers ................ 34
  3.3 Experimental Analysis .................................. 35
    3.3.1 Experiments to Simulate Static CDA Markets .......... 36
    3.3.2 Experiments to Simulate Dynamic CDA Markets ....... 37
  3.4 Summary .............................................. 46

4 Soft Asks and Soft Bids 49
  4.1 Motivation ........................................... 50
  4.2 Definitions .......................................... 50
  4.3 Experimental Results and Analysis .................... 51
    4.3.1 Experimental Results for Markets Favoring Agents ... 52
    4.3.2 Experimental Results for Markets Going Against Agents 52
  4.4 Observations ........................................... 59
  4.5 Agents with Adaptive Soft Asks or Bids ............... 61
    4.5.1 Eagerness ........................................ 61
    4.5.2 Enhancing Bidding Strategies for Sellers and Buyers by
      Adaptive Soft Asks and Soft Bids ..................... 63
  4.6 Experimental Evaluation ................................ 64
    4.6.1 Experimental Setup ................................ 64
    4.6.2 Experimental Results ............................. 66
    4.6.3 Summary and Discussion ......................... 66
  4.7 Summary ................................................ 69

5 Adaptive Judgement of Price Acceptability 71
  5.1 Motivation ........................................... 72
  5.2 Definitions .......................................... 72
  5.3 Experimental Results and Analysis .................... 73
    5.3.1 Experimental Setup ................................ 73
    5.3.2 Experimental Results and Analysis ................. 74
  5.4 Agents with Adaptive Judgement of Price Acceptability . 77
  5.5 Experimental Evaluation ................................ 79
    5.5.1 Experimental Setup ................................ 79
    5.5.2 Experimental Results ............................. 80
  5.6 Summary ................................................ 82
# Contents

6 Adaptive Time Strategies .................................................. 83
   6.1 Preliminaries .................................................................. 84
   6.1.1 Related Work .......................................................... 84
   6.2 Time Strategies ............................................................. 85
      6.2.1 Motivations .......................................................... 85
      6.2.2 Definitions of Time Strategies ................................. 86
   6.3 Illusory Seller’s or Buyer’s Market in CDAs with a Fixed Deadline 87
      6.3.1 Agents Trading in CDAs with a Fixed Deadline .......... 87
      6.3.2 Illusory Seller’s or Buyer’s Market ......................... 88
   6.4 Circumstance-Dependent Softness ................................. 93
   6.5 Effect of Different Submission Time ............................... 98
   6.6 Adaptive Mechanisms for Sellers and Buyers to Utilize Time Strategies ................................. 106
      6.7 Experimental Evaluation of Adaptive Mechanisms .......... 109
         6.7.1 Experimental Setup ......................................... 109
         6.7.2 Experimental Results for Sellers ............................ 110
         6.7.3 Experimental Results for Buyers ......................... 112
         6.7.4 Discussion .................................................. 112
   6.8 Summary ................................................................. 114

7 Discussion of the Results .................................................... 115
   7.1 The Characteristics of Agent Oriented CDAs .................... 115
   7.2 Scenarios in Which Results Can Be Applied .................... 117

8 Conclusions and Future Work ............................................. 121
   8.1 Conclusions ............................................................ 121
   8.2 Possible Future Research Directions .............................. 123

Bibliography ................................................................. 127

Index ................................................................................. 139
Preface

Continuous Double Auction (CDA) is an efficient market institution for real-world trading. Negotiation capabilities for software agents are a central concern. Especially, agents need to be able to prepare bids for and evaluate offers on behalf of the users they represent, with the aim of obtaining the maximum benefit for their users. They do this according to some bidding strategies. However, in many cases, on the one hand, determining which strategy to employ is a complex decision-making task because of the inherent uncertainty and dynamics of the auction market; on the other hand, strategies described in the literature do not adapt very well to dynamic markets. To this end, this book is concerned with developing novel bidding strategies for CDAs and enhancing the performance of different strategies in CDAs with respect to adaptivity by designing some tools for general use.

In this book, we focus on two types of CDAs. One is the CDA with a deadline of an inactive interval. Another is the CDA with a fixed deadline. Three kinds of adaptive behaviours are proposed to enhance the performance of the most widely adopted strategies in CDAs in the literature. They are adaptive softness, adaptive judgement of price acceptability, and adaptive time strategies. First, in the CDA with a deadline of an inactive interval, we design novel adaptive strategies, named Adaptive Attitude strategies, based on eagerness. Eagerness indicates the current supply and demand relationship from the agent’s own point of view. To compute the value of eagerness, fuzzy sets and fuzzy logic are used to cope with the significant degrees of uncertainty in CDA markets. We define two kinds of adaptive behaviours: adaptive softness and adaptive judgement of price acceptability. Both of them resemble human traders’ behaviours to compromise and set thresholds on acceptable prices in the trading process of real-life markets and can enhance the performance of various strategies. Secondly, in CDAs with a fixed deadline, we ourselves research the time strategies. In this market, every agent is aware of importance of timing. Therefore adaptive time strategies are introduced to guide the agent to arrange his behaviour according to time, which can enhance the performance of different strategies. Both the novel strategies and the enhanced strategies have been demonstrated to be superior in a wide range of CDA circumstances. We show that eagerness is a practical solution for this class of application. We believe that this work represents an important step towards adapting agents in auctions.

Through the work described in this book, Adaptive Attitude (AA) strategies have been demonstrated to be superior in a wide range of CDA scenarios. Moreover, three kinds of adaptive behaviours have been shown to greatly enhance the performance of the most widely adopted strategies in CDAs.
Chapter 1

Introduction

1.1 Agent-Based Auctions in Electronic Commerce

1.1.1 Auctions in Electronic Commerce

With the advent of global computer networks, in particular the Internet and the World Wide Web, electronic commerce (e-commerce) has been taking an increasingly important role in many organizations [50]. It provides a faster, cheaper, more personalized, and more agile way for businesses to interact with their customers and their suppliers. Auctions of various kinds are efficient mechanisms to allocate resources in electronic commerce. In this context, online auctions, institutions where goods are traded on the Internet by the process of bidding and allocating through competition, are among the most widely studied and employed means of interaction [5]. Such online auctions are prevalent because they are an efficient and effective method of allocating goods or services [128], [103], [93].

Auctions come in many different forms, each with its own rules and ensuing properties [99], [97], [114]. In English auctions [20], [65], the auctioneer starts with a reservation price and solicits successively higher public bids from the bidders until no one increases the bid, and the last bidder is the winner. First-price sealed bid (FPSB) and second-price sealed bid (SPSB, also called Vickrey) auctions are auctions in which bidders submit sealed bids to the auctioneer and the bidder who submits the highest bid wins [65]. In FPSB, the winner pays the highest bid. In SPSB, the bidder wins but pays the second highest bid [114]. In Dutch auctions, the auctioneer starts with a high price and decreases it until a bidder accepts the current price. In continuous double auctions (CDA), buyers submit increasingly higher bids and sellers submit increasingly lower asks at any moment during a trading period and transactions occurs when the highest bid is at least as high as the lowest ask [41], [29], [20], [36], [96].

On the basis of the classical auction types described above, variants have been designed in recent years. For examples, a combinatorial auction [56], [57],
[47], [118], [55], [129], [23] is a type of auction where bidders can submit bids to buy a bundle of multiple goods. In sequential or simultaneous *multiple auctions*, a bidder needs to monitor all the relevant auctions, decide which one to bid in, and determine what to bid in order to get the goods at the best deal [91], [9], [110], [32], [51], [38], [39], [40], [33], [132]. In *multi-attribute auctions*, multiple attributes of the goods, such as delivery date, efficiency, volume, etc., are considered by bidders, who aim at obtaining an overall rating for the bid from ratings of the individual attributes of the bid [26], [44], [66]. Besides these variants of auctions, most recently, online search engine advertising has become an appealing approach to highly targeted advertising, and is the major source of revenue for modern web search engines such as Google\(^1\) and Yahoo\(^2\) [11]. The process of determining which ads get assigned to which keywords and how much each advertiser pays is resolved via keyword auctions. Advertisers choose which keywords they want to bid on and participate in Generalized Second-Price auctions for those keywords [30].

Auction scenarios consist of two clearly distinct components: *protocols* and *strategies* [7]. The former defines the valid behaviours of agents during interactions. For example, in an English auction, an agent needs to bid at the current price plus a bid increment. The latter is the method an agent employs to achieve his negotiation objectives within the specified protocol. For example, in an English auction, a strategy that could be adopted is to bid a small amount more than the current highest bid and to stop bidding when the agent’s reservation price is reached. Generally speaking, the protocol is set by the marketplace owner before execution, and is publicly known to all the participants. In contrast, the strategy is determined by each individual participant and is typically private. Nevertheless, protocols and strategies are inextricably linked because the effectiveness of a strategy is very much determined by the protocol. Thus a strategy that is effective for one protocol may perform very poorly or may even be invalid for other protocols. Moreover, for some protocols, the optimal bidding strategy is easy to determine and simple to compute. For example, the strategy proposed above for an English auction is in fact optimal if all the agents have their private valuations of the goods. However, generally there is no such simple solution and developing a good strategy is a significant research challenge.

### 1.1.2 Agent-Based Auctions in Electronic Commerce

In order to harness the full potential of various types of auctions, it is important to increase both the degree and the sophistication of the automation. To achieve this, *software agents* are needed, which are representatives of human users to fulfil their requirements and expectations and consequently need to be tailored to achieve those humans’ aims [95]. A key aspect of such trading agents is that they need to interact with one another in order to affect trades (i.e., to buy and sell goods or services) [58].

\(^1\)http://adwords.google.com/.

\(^2\)http://www.yahoo.com/.
In such environments, agents can perform a variety of different roles: (i) monitoring auctions in order to keep the user informed of the latest progress of various auctions, (ii) analyzing the market situation and history in order to predict probable trends, (iii) deciding when, how many and how much to bid in order to get the best deals.

The more these activities can be automated, the more time can be saved for the user. Moreover, in complex settings agents are likely to be more effective than human bidders. This is partly a matter of speed (agents can process information more quickly than humans), but also because agents can more easily and more systematically perform the complex decision making required to operate effectively in multiple auction settings. Preliminary evidence for this [25] shows that software agents outperform their human counterparts in continuous double auctions. Using software agents can thus increase the chance of obtaining the goods and bringing greater profit and satisfaction for the user [2], [26], [32], [91], [107]. When more agents are used in the market, the market becomes more efficient [91]. Based on these factors, automation of bidding becomes possible, in which agents carry out trading, and hence human traders can save considerable time and effort [6].

1.1.3 Motivations of this Work

Automation of bidding is complex. Given the variety of auction protocols, it is perhaps not surprising that the bidding strategies of the participants cover a similarly broad spectrum of behaviours. In short, there is no optimal strategy that can be used in all cases. To be effective, bidding strategies need to be tailored to the type of the auction in which they are to be used. Perhaps the key challenge in this area is to design effective and efficient strategies that agents can use to guide their bidding behaviour. Although challenging, such developments are necessary if trading agents are to realise their full potential. Furthermore, we believe that the existence of effective strategies will mean that online auctions can be more readily deployed as a practical market protocol. Given this background, the research reported in this book addresses exactly this challenge for a complex and dynamic e-commerce auction scenario, continuous double auctions.

If we take a look at human traders in real-life markets, the following situations can be detected. When human traders buy or sell goods in the CDA market, they will naturally develop some subjective feelings. In particular, when it is difficult to trade goods, human traders will be eager for more transactions, on the totality of which they hope to gain more profit. On the other hand, if they find it easy to trade goods, they will be tempted to obtain more profit in each transaction so as to earn more profit in the end. Eagerness is a natural feeling for human traders. Besides the feeling of eagerness, human traders may make different degrees of compromise in return for more transactions when encountering some difficulties in trading; they may set thresholds on the price acceptable to them in the current market and adjust the values of the thresholds with the dynamic market, both of which will improve profit. The feeling of eagerness of human traders also inspires
agents to develop eagerness with the market on the basis of the trading history of the market, which tells the agent whether it is easy or difficult to trade. Guided by eagerness, an agent is able to behave adaptively to make compromises or to judge the price acceptability with the dynamic market. However, little work has been done in bidding negotiation to simulate human traders’ feeling and behaviours in real-life markets. With the aim of more adaptive and efficient strategies, we develop new tools for general use to enable agents utilizing existing bidding strategies to behave more adaptively to enhance their profit.

Another case that we notice in real-life markets is that many online auctions have a fixed deadline before which the trading process must be terminated. Therefore human traders in the auctions take a time effect into account when bidding. When it is easy for human traders to make transactions, they will wait some time before really getting involved in the trading process. Otherwise, they will speed up their bidding process if possible before each bid submission. This kind of behaviour will usually benefit human traders. Given this, time strategies are proposed in agent-based continuous double auctions with a fixed deadline where each round is terminated within a pre-specified deadline. Agents in this kind of continuous double auctions are aware of the time, including the current time and the deadlines. Nevertheless, the effect of time strategies in such types of continuous double auctions has never been investigated. Hence, we seek to develop adaptive time strategies to enhance existing strategies for this case.

1.2 Research Aims

In designing new bidding strategies to enhance existing bidding strategies for CDAs, there are a number of common issues that need to be dealt with. In addition, we believe that it is possible to identify a range of concepts and technologies that form a solid foundation for tackling such problems in a broad range of situations. We now consider each of these in turn.

First, an agent needs to be adaptive so that he can tailor his bidding strategy according to latest state of the environment in which he is situated. Being adaptive is particularly important in cases where the environment is subject to changes. These can happen, for example, when the agent is trading with the same (or similar) partners or opponents repeatedly. In such cases, the agent can adapt his behaviours according to the behaviour of other agents so that he can obtain a better payoff. However, when things changed, often due to the introduction of new traders, the parameters which characterise the strategy need to be changed accordingly. This is impractical to achieve by manually adjusting the parameters, since this is a complex and error-prone process. So it is desirable that the agent adapt himself autonomously.

Second, an agent needs to make some degree of compromise when generating and responding to bids. For example, in a CDA, if a buyer agent is going to bid $100, but the lowest ask in the market is $101, then the buyer agent may benefit
by compromising and bidding 1% higher than he is going to bid in order to make the trade.

Third, an agent needs to be flexible in setting and adjusting thresholds of acceptable price according to the latest state of his environment. This procedure is usually based on the agent’s ability to detect the market environment in real time so that the values of thresholds can be adjusted in a meaningful way. In details, if a seller has many transactions recently, he should set the thresholds high; if a seller seldom makes transactions, should will set the thresholds low. When using the same strategy, adjusting thresholds of acceptable price adaptively can make a significant difference to the outcomes obtained.

Fourth, an agent needs to be able to manage his behaviours by time if there is a fixed deadline to terminate each round of a CDA. With a fixed deadline, if a human trader finds that he can easily trade all his goods, then he should not be anxious and should be willing to wait for some time before beginning to trade in each round.

Given these aims, we propose to use a range of techniques based on fuzzy set theory to cope with the inherent uncertainty present in all of these activities. This uncertainty can come from a number of sources including sellers, buyers, the supply and demand relationship in the market, or the remaining time before the deadline. For example, the number of traders and the decision strategy of the other traders are generally unknown to an agent. Fuzzy set theory has proved to be effective to handle uncertainties in a range of applications [34], [131], [53]. Moreover, the intuitive nature of fuzzy logic and its embodiment in fuzzy rules make it readily comprehensible to agent designers.

This work is concerned with the design of bidding strategies for continuous double auctions and techniques enhancing different bidding strategies for continuous double auctions. The first aspect of our work involves developing novel strategies for buyer agents and seller agents in CDAs. Specifically, a buyer agent needs to decide when to place a bid and at what price; a seller agent needs to decide when to place an ask and at what price. The other major purpose of this work is to explore the design and implementation of general tools to enhance the performance of various strategies in CDAs that exist in the literature. To effect such performance enhancement, an agent needs to: (i) adapt himself to suit the prevailing market context, such as the change in the demand and supply in the market and other bidders’ strategies; (ii) make compromises with his bids and asks so that he can get more transactions when encountering difficulties in trading; (iii) set price thresholds on the acceptable asks or bids; (iv) make good use of time when trading in continuous double auctions with a fixed deadline.

1.3 Research Contributions

The work described in this book makes a number of contributions to the state of the art in the area of bidding strategies that autonomous trading agents can use
Chapter 1. Introduction

in a number of CDAs. Specifically,

- We develop a novel Adaptive Attitude (AA) bidding strategy that agents can use to participate in CDAs [67] [73]. The effectiveness of the strategy is demonstrated by empirically benchmarking it against the major strategies that have been proposed in the literature. The evaluation shows that our AA strategy is superior in a wide range of market situations.

- We propose to use soft asks and soft bids in agent-based CDAs [68]. An agent changes his ask or bid to a soft ask or soft bid by adding a degree of softness around the determined value. An adaptive mechanism is developed for agents to vary the degree according to their perception of the marketplace in which they are operating. This mechanism has been tested on the major strategies for CDAs and empirically demonstrates its ability to remarkably enhance their performance.

- We define and implement, for the first time, an adaptive judgement of price acceptability that an agent can use to set thresholds for the asks or bids [70]. If the outstanding ask or the outstanding bid is very profitable, then the agent can directly accept it. If the outstanding ask or the bid is very poor, then the agent can decline it right away. Experimental results show that, after integrating the adaptive judgement of price acceptability, an agent attains a higher overall performance.

- We introduce for the first time adaptive time strategies for agents to utilize in continuous double auctions with a fixed deadline [71]. If it is easy to trade his goods, an agent should wait for some time before beginning the process. Otherwise, the agent should try to expedite his bidding process. A special market situation, illusory seller’s or buyer’s market, is defined. An illusory seller’s market (buyer’s market) occurs when supply is larger (smaller) than demand whilst the seller (buyer) finds it is easy to trade his goods. To cope with an illusory seller’s or buyer’s market, circumstance-dependent negative softness is proposed, which enables agents to increase profit without making compromises. Experimental results show that an agent experienced with integrating adaptive time strategies in a wide range of continuous double auctions with a fixed deadline attains a better performance than a corresponding agent without such experience.

1.4 Book Structure

The rest of this book is structured in the following manner:

Chapter 2 surveys agent-based continuous double auctions and bidding strategies. For the former, we define agents in CDA scenarios and then give the basic continuous double auction mechanism and its variants. For the latter, strategies of
agents in CDAs as reported in the literature are introduced and discussed. Evaluation criteria of the strategies and methodologies to analyze them are presented and investigated as well.

Chapter 3 concentrates on CDAs and new algorithms are designed for buyer and seller agents. Eagerness is first defined based on short-term attitude and long-term attitude in order to reflect the current supply and demand relationship from the agent’s own point of view. Moreover, we show how an agent can, with the guidance of eagerness, dynamically adjust his bidding behaviour to respond effectively to changes in the marketplace. We then demonstrate, by empirical evaluations, how our agents outperform other agents, employing six conventional strategies previously developed for CDAs in the literature.

Chapter 4 defines soft asks and soft bids, and an adaptive mechanism is designed that a software agent can use to adaptively adjust the degree of softness with the dynamic CDA market. The notion of eagerness is extended from that in Chapter 3. Fuzzy sets and fuzzy logic are employed to determine the value of eagerness. The effectiveness of the adaptive mechanism is empirically illustrated, i.e., when an agent (using any of five major bidding strategies previously developed for CDAs) incorporates the adaptive mechanism, his performance is generally enhanced a lot in a wide range of CDA market scenarios.

Chapter 5 gives the definitions of the judgement of price acceptability for seller agents and buyer agents. An adaptive mechanism is proposed and implemented. A software agent can use the mechanism to adaptively adjust the thresholds of price acceptability according to eagerness. Empirical evaluation demonstrates that agents, employing the major bidding strategies for CDAs proposed in the literature, can remarkably enhance their performance in general in a wide range of market scenarios after integrating the adaptive mechanism.

Chapter 6 discusses strategies used in continuous double auctions with a fixed deadline where each round of CDAs is ended within a fixed deadline. In such CDA markets, agents are aware of both the current time and the deadline. Time strategies are established and adaptive mechanisms are designed for the first time. In particular, an illusory seller’s or buyer’s market is identified. Circumstance-dependent negative softness is proposed to handle this special market situation. We show, through empirical evaluation against a number of bidding strategies proposed for CDAs in the literature, that agents employing the adaptive mechanism perform effectively and robustly in a wide range of CDA scenarios.

Chapter 7 discusses the main characteristics of the CDA markets we focus on in this book. A comparison between the agent-based CDA markets discussed in this book and the CDA markets in real life is given. We then discuss the conditions under which strategies and tools proposed in this book are applicable.

Chapter 8 concludes the book. We recap the main contributions of this book and describe pathways for future work.
Chapter 2

Agent-Based CDAs and Bidding Strategies

2.1 Agent-Based Continuous Double Auctions

The role of agents in auctions is to represent their users, who may be buyers or sellers or the auctioneer, to achieve particular objectives [58], [54], [81], [83], [50]. Although there are many attributes concluded in the literature, some attributes are essential for CDAs we discuss in this book. First of all, we define exactly what we mean by the term “agent” in CDAs. An agent in CDAs is a software package that can be viewed as a delegate of his\(^1\) user to achieve a good performance which usually means a good profit. To this end, an agent must exhibit the following properties:

- Autonomy: The agent is capable of making decisions about what actions to take without constantly referring back to his user;
- Adaptivity: The agent is capable of adjusting himself to environmental conditions based on trading history, etc.;

Except for these two properties as a must, an agent may possess one or more of the following attributes conditioned on the specific environment where he is situated [50], [81], [127]:

- Proactiveness: The agent is capable of taking the initiative rather than acting simply in response to his environment;
- Reactivity: The agent is capable of responding appropriately to the prevailing circumstances in dynamic environments;

\(^1\)The reader will note that we now refer to the agent with words such as “his” rather than “its” in order to emphasize the human-like functioning of the agent.