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Explorations in evolutionary design of online auction market mechanisms

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Abstract

This paper describes the use of a genetic algorithm (GA) to find optimal parameter-values for trading agents that operate in virtual online auction 'e-marketplaces', where the rules of those marketplaces are *also* under simultaneous control of the GA. The aim is to use the GA to automatically design new mechanisms for agent-based e-marketplaces that are more efficient than online markets designed by (or populated by) humans. The space of possible auction-types explored by the GA includes the continuous double auction (CDA) mechanism (as used in most of the world's financial exchanges), and also two purely one-sided mechanisms. Surprisingly, the GA did not always settle on the CDA as an optimum. Instead, novel *hybrid* auction mechanisms were evolved, which are unlike any existing market mechanisms. In this paper we show that, when the market supply and demand schedules undergo sudden 'shock' changes partway through the evaluation process, two-sided hybrid market mechanisms can evolve which may be unlike any human-designed auction and yet may also be significantly more efficient than any human designed market mechanism.

Keywords: Online auction marketplaces; e-Marketplaces; Automated market mechanism design; Trader-agents; ZIP traders; Genetic algorithms

1. Introduction

For thousands of years, buyers and sellers have come together to exchange money for goods or services. Economists use the word 'auction' to refer to the mechanism (or rules) by which buyers and sellers interact in such marketplaces. Almost all traders in the global international financial markets interact via a particular form of auction market mechanism known as the *continuous double auction* (CDA), more details of which will be given later.[1] The CDA has been the subject of much study by economists, partially because it is so important in the world of finance, but also because CDA markets typically exhibit a very attractive characteristic: experimental studies have demonstrated that the transaction prices in a CDA market rapidly converge on the market's theoretical *equilibrium price*. Stu-

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[1] It is beyond the scope of this paper to provide a review of all possible auction mechanisms: for a recent relevant paper, see Ref. [25].

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dents of microeconomics know the equilibrium price as the price at which the market's supply and demand curves intersect; but, colloquially, the equilibrium price is important because if transactions are taking place at off-equilibrium prices then someone somewhere in the market is being ripped off. Hence, rapid equilibration is desirable in any auction. The precise reasons why CDA markets typically exhibit rapid and stable equilibration are still the topic of research and debate (see e.g. Ref. [12]).

With the advent of e-commerce, various forms of auction mechanism have become very popular for online trading, and web-based auction sites such as www.ebay.com have proven highly successful. As auctions dematerialize, moving online and becoming virtual 'e-marketplaces', it becomes perfectly plausible for software-agent 'robot' traders to participate in those auctions. In comparison to human traders, such 'bots' have the advantage of being very fast and very cheap, and in principle they can assimilate and act on volumes of data that would swamp even the most able of human traders.

ZIP (zero-intelligence-plus) artificial trading agents, introduced in Ref. [3], are software-agent 'trader bots' that use simple machine learning techniques to adapt to operating as buyers or sellers in open-outcry auction-market environments similar to those used in Smith's [22] pioneering experimental economics studies of the CDA and other auction mechanisms. ZIP traders were originally developed as a solution to the pathological failures of Gode and Sunder's [13] 'ZI' (zero-intelligence) traders, but recent work at IBM by Das et al. [11] has shown that ZIP traders (unlike ZI traders) consistently out-perform human traders in human-against-robot experimental economics CDA marketplaces. The ZIP traders consistently made profits a few percentage points higher than did the human traders they were competing against. Das et al. [11] wrote that the '. . . successful demonstration of machine superiority in the CDA . . . could have a . . . powerful financial impact—one that might be measured in billions of dollars annually', and in their conclusions they speculate on the future possibility of online e-marketplaces currently populated by human traders becoming populated entirely by trader agents.

The operation of ZIP traders has been successfully demonstrated in experimental versions of CDA markets similar to those found in the international financial markets for commodities, equities, capital, and derivatives; and in posted-offer auction markets similar to those seen in domestic high-street retail outlets [3]. In any such market, there are a number of numeric parameters that govern the adaptation and trading processes of the ZIP traders. In the original 1997 version of ZIP traders, the values of these were set by hand, using 'educated guesses'. However, subsequent papers [4,5] presented the first results from using a standard technique to automatically optimize these parameter values, thereby eliminating the need for skilled human input in deciding the values.

Prior to the research described in Ref. [6], in all previous work using artificial trading agents—ZIP or otherwise—the market mechanism (i.e. the type of auction the agents are interacting within) had been fixed in advance. Well-known market mechanisms from human economic affairs include: the English auction (where sellers stay silent and buyers quote increasing bid-prices), the Dutch Flower auction (where buyers stay silent and sellers quote decreasing offer-prices); the Vickery or second-price sealed-bid auction (where sealed bids are submitted by buyers, and the highest bidder is allowed to buy, but at the price of the *second-highest* bid: game-theoretic analysis demonstrates that this mechanism encourages honesty and is robust to attack by dishonest means); and the CDA (where sellers announce decreasing offer prices while *simultaneously and asynchronously* the buyers announce increasing bid prices, with the sellers being free to accept any buyer's bid at any time and the buyers being free to accept any seller's offer at any time, in the absence of an auctioneer).

In this paper, we explore in detail the some specific consequences of asking the following question: if, as Das et al. [11] speculate, trader agents will come to replace human traders in online e-marketplaces, then why should those online e-marketplaces use auction mechanisms designed by humans, for humans? Perhaps there are new market mechanisms, *suitable only to populations of robot-traders,* that are more efficient (or otherwise more attractive) than currently known human-based mechanisms.

Designing new market mechanisms is hard, and