Towards Automated Trading Based on Fundamentalist and Technical Data

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Abstract. Autonomous trading is often seen as artificial intelligence applied to finance by AI researchers, but it may also be a way to motivate the development of autonomous agents, just like robot soccer competitions are used to motivate the research in mobile robots. In fact, some initiatives could be observed in recent years, for instance [1] and [2]. In this paper, we present a multiagent system composed by several autonomous analysts that use fundamentalist information in their reasoning process. These fundamentalist information are composed by company profit, dividends, data related to the company economic sector among others. This kind of information is rarely used on autonomous trading, because most of the agents deal only with technical information, which is composed by price and volume time series. Furthermore, we do not find a open source stock market simulator with support to fundamentalist trader agents. We then created a significantly extended version of the open source financial market simulation tool, called AgEx. This designed version provides also fundamentalist information about the trader's assets. As well as, makes more efficient the exchange of messages within AgEx. This efficiency allows traders that may submit orders in very short intervals of just some seconds or even some fraction of second, to use AgEx as a test platform. Using this new version of AgEx, we implemented and tested the multiagent system based on fundamentalist agents, that we call FAS. The achieved results are presented and analyzed.

Keywords: multiagent systems, automated trading, autonomous agents.

1 Introduction

Automated trading [3] may be an interesting environment for the development and test of multiagent systems and autonomous agents. In fact, we may observe the use of several AI techniques in automated trading, for instance: neural networks [4], reinforcement learning [5, 6], BDI architectures [7], SWARM approaches [8]. Often, these initiatives relay on time series of price and/or trade volume. Despite the fact that these data are relevant, human experts many times use also economic information about the company (such as profit, dividends policy and so on), about the economic sector (size

and growth projections) and general economy (growth projections, volatility analysis, etc.). The analyses based on this kind of data is commonly called fundamentalist, in opposition to the analyses based on price and volume time series, which is called technical analyses.

We present in this paper a multiagent system composed by autonomous traders that use fundamentalist information in their reasoning processes. These traders were implemented and tested. The results achieved are presented and analyzed. Furthermore, we present a significantly extended version of the open source financial market simulation tool, called AgEx. This extended version provides fundamentalist information about financial assets. The designed extensions also allow AgEx to be used for traders that may submit orders in very short intervals of just some seconds or even some fraction of second. We believe this tool may be useful for others researchers in automated trading and even for researchers that intend to test their systems in a complex and dynamic environment as financial market.

This paper is organized as follows section 2 describes the AgEx architecture highlighting the new features added to previous version [3]. In section 3, we present the FAS multiagent systems based on fundamentalist traders. The experiments and achieved results using FAS under AgEx are presented and discussed in section 4. Finally, we present some conclusions and suggestion to future work in section 5.

2 AgEx Architecture

Figure 1 presents the AgEx architecture [3] with its main components and communications links among trader agents and their human investors. The gray rectangles represent software agents (traders, manager and broker), while the circles represent the owners of the agents and a human administrator of AgEx. The entity represented by a white rectangle is a software module that is too simple to be classified as agent, and performs the actions determined by agents, such as buy and sell order executions. The component AgEx Data is just a database of real operations that took place in some real exchange and it may be used in simulations as described later. The AgEx system is composed by three components, which are described next:

- **Trader Agent**: It is responsible to decide and to submit buy or sell orders to some predefined assets. In fact, these agents use the AgEx as a simulation platform framework for communication and life cycle management. Therefore, they are represented over AgEx border in figure 1. The AgEx system may provide services for many traders simultaneously, as shown in figure 1.
- **AgEx Manager**: This agent is responsible to validate and to process messages addressed to AgEx system. It sends the valid messages to execution that are performed by a software module, called AgEx Broker. The execution results are received by the manager and sent to the traders that submitted the order.
- **AgEx Broker**: It receives and executes buy or sell orders and informs the AgEx Manager about the result of execution.

The trader agents and the AgEx manager agent are synchronized by message exchanges. The manager defines the duration of each cycle (time step) and their transitions. All

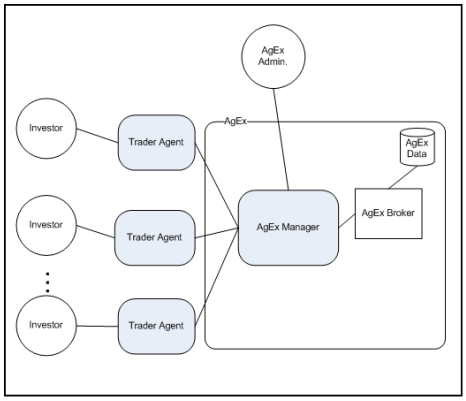

Fig. 1. AgEx architecture.

traders must be able to get the needed information, deliberate and submit orders within the interval of one time step. Whenever a trader does not complete these tasks within one time step, the system raises an overrun exception. One trader agent does not know in advance at which price one market order is executed, just like it happens in real markets. Furthermore, agents are not allowed to access price information beyond the current cycle. These features provide more realism to the simulation and avoid that one trader gets privileged information.

The AgEx database was changed to provide a structure with historic price and volume time series, financial data, financial indicators and macroeconomic data for the various stocks traded in the financial market. This data is transmitted to the agents through messages in Agent Communication Language (ACL) that uses an ontology specially defined for AgEx. This ontology is based in models developed by FIPA [9] and implemented by JADE platform.

3 Fundamentalist Agents System

In this section, it is presented the architecture of the multiagent system FAS (Fundamentalist Agents System). FAS works as one trader agent from the point of view of AgEx, because it manages one portfolio. However, it is composed by of one software module, **growth estimator**, and three kinds of agents, **price analyst**,**indexes analyst** and **manager**, which are briefly describe next.

- **Growth Estimator** is a software module that, through different estimation methods, provides to the *price analysts* and *indexes analysts* the estimative of companies' profit and EBIT growth to be used into the fundamentalist analyses executed by each one of those *analysts*.
- **Price Analyst** is an agent specialized in one of the various types of fundamentalist analysis based on models to estimate the stock fair price. This fair price after being determined is passed to the *manager* and gives support to the decision of buying or selling stocks.

– **Indexes Analyst** is an agent that uses strategies of fundamentalist indicators to determine if a stock is under or overvalued. Its advice is passed to the *manager* and gives support to the decision of buying or selling stocks.
– **Manager** is an agent that selects a stock to be analyzed, passes data about this stock to the *indexes* and *price analysts*, gathers the analysis of each one of those analysts, determines the selected stock fair price and executes buy or sell orders according to this fair price. The fair price is a consolidation of the analysis made by each one of the indexes and price analysts balanced by the performance of each one of them in the previous periods.

The FAS architecture is presented in figure 2. FAS works on six sequential steps, as shown in figure 2, that are performed by its components. Each one of FAS components,**growth estimator**, **price analyst**,**indexes analyst** and **manager** are described in details in the following subsections.

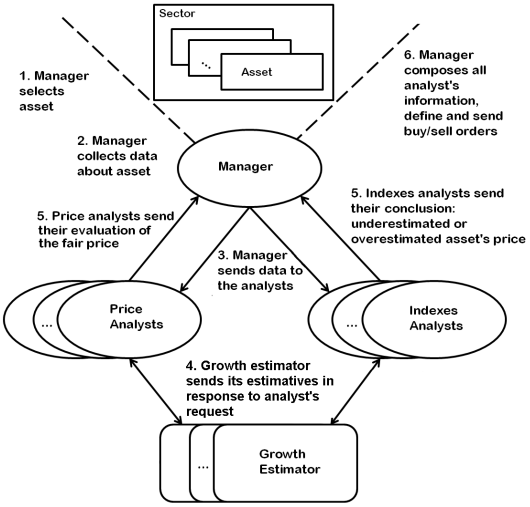

Fig. 2. FAS architecture

3.1 Growth Estimator

The company growth rate estimation is really subjective and contains knowledge of professional analysts about the company and the economic sector which the company belongs to. Therefore, we used simplified versions of some common financial market estimation methods to estimate the perpetual company profit and EBIT growth. In order to achieve those estimates, the *growth estimator* receives as input of an analyst (Indexes or Price Analyst) financial data of the company (payout ratio, ROA, debt, equity, tax rate and interest rate) and macroeconomic data (GDP growth of the company's country).

The *growth estimator*, that is assigned with one method of estimation, after receiving the inputs, executes the method of estimation and returns the estimative to the Analyst that sent the inputs. The growth estimator used by the analyst will be defined by what kind of model or strategy the analyst is using. If the model or strategy doesn't have any restrictions about what kind of estimated growth rate can be used (EBIT or profit growth), the analyst will use all kinds of estimations to obtain from his model or strategy as many inputs as possible for the *manager*. The *growth estimator* is a software module that implements one of the four estimation methods following :

- Estimation by compound annualized growth rate of the last five years of GDP growth of the country that the company is held. This estimation is based on the hypothesis adopted by fundamental analyses that points out that the analysis only applies to companies with profit and EBIT growth similar to the economic growth of the country. The last five years are used to decrease the effects of a recent fall in GDP that would undervalue the potential company growth.
- Estimation by compound annualized growth rate of the last three years of GDP growth of the country that the company is held. This estimation is based on the hypothesis adopted by fundamental analyses that points out that the analysis only applies to companies with profit and EBIT growth similar to the economic growth of the country. The last three years are used to capture the effects of a recent boom in GDP that would leverage the potential growth of the company.
- Estimation of profit growth based on financial data according to these formula

$$\mathrm{EPS} = (1 - \mathrm{Payout})\{\mathrm{ROA} + \frac{D}{E}[\mathrm{ROA} - j(1 - i)]\}. \tag{1}$$

  This growth is based on the relation between financial indicators.
- Estimation of EBIT growth based on financial data according to this formula:

$$\mathrm{EBIT} = (1 - \mathrm{Payout})\mathrm{ROA}. \tag{2}$$

  These estimations were imposed to simplify the process of estimation of the company growth necessary to automate the fundamental analyses.

3.2 Price Analysts

The *price analysts* have as inputs company financial data (EBIT, debt, equity, dividend, outstanding stocks, depreciation, investments, interest rates, tax rates, working capital and beta), macroeconomic data (risk free rate and historic premium) and company profit or EBIT growth rate estimated by the *growth estimator*. The estimated growth rate used depends of the model restrictions about what kind of growth can be used (EBIT or profit growth) and if there is none, the *price analysts* use all to provide as many inputs as possible for the *manager*. The input data is passed by the *manager* according to the stock that the *manager* wants to buy or sell.

From the input data given by the *manager*, the *price analyst* calculates more elaborate financial indicators such as free cash flow, weight average cost of capital, cost of equity, and uses the Gordon model and the Free Cash Flow to Firm model [10] to estimate the fair price to be paid for the stock selected by the *manager*.

The fair price obtained is passed to the *manager* that weights it according to the performance showed by the price analyst in the previous periods.

3.3 Indexes Analysts

The *indexes analysts* have as input company financial data (profit, equity, outstanding stocks, revenue, payout, ROE, stock price and beta), macroeconomic data (risk free rate and historic premium) and company profit or EBIT growth rate estimated by the *growth estimator*. The estimated growth rate used depends of the fundamentalist indicator strategy restriction about what kind of growth can be used (EBIT or profit growth) and if there is none, the *indexes analysts* use all to provide as many inputs as possible for the *manager*. The input data is passed by the *manager* according to the stock that the Manager wants to buy or sell. The *indexes analysts* uses one of the fundamentalist indicator strategies described as following:

- The fundamentalist indicator Price/Profit (PL) has the following strategies: (1) Select stock that has the lowest market PL among the stocks of the same sector. This stock probably is undervalued, (2) Compare the market PL value with the expected PL value according to basic financial data using different profit growth rate estimations. If the market PL is lower, it is probable that the market is undervaluing the company, (3) Compare market dividend yield with risk free rate. If the market dividend yield is higher, it is probable that the stock is undervalued and(4) Compare market dividend yield with the expected dividend yield value according to basic financial data using different profit growth rate estimations. If the market dividend yield is lower, it is probable that the stock is undervalued.
- The fundamentalist indicator Price/Book Value (PBV) has the following strategies: (1) Select stock that has the lowest market PBV among the stocks of the same sector. This stock probably is undervalued, (2) Compare the market PBV value with the expected PBV value according to basic financial data using different EBIT growth rate estimations. If the market PBV is lower, it is probable that the market is undervaluing the company and (3) Compare market PBV value with company ROE. If PBV is the lowest and ROE is the highest among stocks of the same sector, it is probable that the market is undervaluing the price of the stock.
- The fundamentalist indicator Price/Sell (PS) has the following strategies: (1) Select stock that has the lowest market PS among the stocks of the same sector. This stock probably is undervalued, (2) Compare the market PS value with the expected PS value according to basic financial data using different profit growth rate estimations. If the market PS is lower, it is probable that the market is undervaluing the company and (3) Compare market PS value with company profit margin. If PS is the lowest and the profit margin is the highest among stocks of the same sector, it is probable that the market is undervaluing the price of the stock.

It is known that these strategies have different results depending on the year and which stock is being used and that the advices of under or overvalued is not a precise value and do not guarantee with 100% that the stock price rises or falls. So, it is possible to use fuzzy logic [11] to transform the fundamentalist indicator value, a crisp value, into a linguistic value of the linguistic variable "*Indexes analyst price*" in a way to serve as entrance for a fuzzy inference system. A system that can be used to obtain conclusions about the fair price to be paid by a stock.

This linguistic variable "*Indexes analyst price*" is the advice returned to the Manager and indicates the pertinence level in which the stock chosen by the Manager belongs to the linguistic values "*Overestimated*", "*Underestimated*" and "*Neutral*". The last value, "*Neutral*", indicates that the fundamentalist indicator do not present enough evidences to be possible to affirm if the stock is under or overvalued. The linguistic variable "*Indexes analyst price*" is returned to the *manager* with the pertinence functions of each possible value and with the crisp value of input (fundamentalist indicator value). For each of the described fundamentalist indicator strategy, these pertinence functions are update dynamically at each new asset selection.

3.4 Manager

The *manager* of a sector is responsible for observe the companies of that sector, gather financial and macroeconomic data necessary to the analysts elaborate their advices and analyses, receive the fair price from the *price analysts* and the advice (linguistic variable) indicating the pertinence level of under and overestimated of the *indexes analyst* and aggregate everything to come to a unique fair price for the selected stock. With this fair price, is possible to buy and sell stocks of the companies in the sector of his responsibility. Therefore, the *manager* manages a portfolio of companies' stock of a sector and uses the analysts to improve his portfolio performance.

During this analysis aggregation process, it is important to consider how trustful those analyses had proven to be. In order to the final fair price to have a major weight of trustful analyses and a minor weight of those who are not. The confidence level of an analysis is measured by the gain that the analyst had with his analyses during the period of evaluation. This period of evaluation is a system parameter and allows to adequate the system to be more or less reactive to the extern environment. However, to determine if a analysis is trustful or not it is also a imprecise value and therefore needs to be made fuzzy to be used as an input in the fuzzy inference system and to come to a conclusion about the final fair price. The *analyst* gain is measured by the gain that the *manager* would have if the decisions of buying and selling the chosen stock were to be taken based only on the analyses about the stock of the evaluated analyst.

This way, if the analysis of the evaluated *analyst* indicates that the stock is "*Underestimated*", the *manager* would have bought the stocks, therefore the position is saved as +1 and the buy price P is also saved. If the analysis indicates that the stock is "*Overestimated*", the *manager* would have sold the stocks, therefore the position is saved as -1 and the sell price P is also saved. If the analysis indicates "Neutral", the positions and prices are kept. The position and price only change if the analysis changes from "*Underestimated*" to "*Overestimated*" or vice-versa. Therefore at the end of the evaluation period, price and positions saved are weight summed to obtain the gain/performance of the *analyst* in the period. Analyst's open positions are closed (positions sum must be zero) at the end of the evaluation period by doing an opposite trade with the market price in order to equalize all *analysts*. During the evaluation period, *analysts* are permitted to sell short in order to have an appropriate performance and fair comparison.

4 Simulated Experiments and Results

In this section, the results of FAS simulation are described and analyzed. In subsection 4.1, the parameters used in FAS simulation, details about the database and the used AgEx configurations are presented. In subsection 4.2, the results obtained by the simulations are shown and analyzed.

4.1 Simulation Characteristics

We performed simulations over a set of five different sectors, where four of those have five companies and one have three. The sectors and the companies chosen were among the biggest american companies of each of the biggest american economy sectors listed in Fortune 500-2008. These companies were selected because of the availability of financial data and to be giants in its sectors which ensures the hypothesis used by the fundamental analyses used in this work. The companies and sectors selected are listed below:

- Oil&Gas: Exxon, Chevron, ConocoPhillips, Valero Energy and Marathon Oil
- Metals: Alcoa Inc., United States Steel Corp, Nucor Corp, Commercial Metals and AK Steel Holding Corp
- Automobiles and Parts: Ford Motor, Johnson Controls and Goodyear Tire & Rubber
- Computer Software: Microsoft, Oracle, Symantec, CA Inc and ADOBE Systems
- Computers and Office Equipments: Hewlett-Packard, Dell, Apple, Xerox and Sun Microsystems

The financial data were obtained in Bloomberg from 2001 to 2008. This database had a bunch of incomplete or missing data. This data were estimated or completed before being inserted into the AgEx database for the simulation. The estimative realized for the six missing data (investments, beta, ROA, ROE, tax rate and interest rate) were :

1. The investment were estimated as: $\Delta\mathrm{GrossFixedAsset} - \Delta\mathrm{AccumlatedDepreciation}$, where Δ is the variation occurred from last year to the current year
2. The beta was calculated from linear regression of the last three years of monthly returns of company stocks against the market index S&P500. This estimative is used by YahooFinance that was used as a comparison base. It is important to keep in mind that beta was calculated for all years from 2001 to 2008 dated from the company financial statement launch.
3. ROA was estimated according to the formula: $\mathrm{EBIT}(1-i)/\mathrm{Assets}$, where EBIT is the earnings before interest and taxes, i is the tax rate and Assets are the total assets owned by the company
4. ROE was estimated according to the formula: $\mathrm{Profit}/\mathrm{BV}$, where BV is the book value of the company equity.
5. Tax Rate was estimated according to the formula: $\mathrm{TaxExpense}/\mathrm{PretaxIncome}$, where Pretax Income is the direct profit coming from the company's activities before the payment of taxes.
6. Interest Tax was estimated according to the formula: $\mathrm{InterestExpense}/\mathrm{Debt}$, where Debt is the company long-term debt.

The AgEx system was simulated in historic mode with prices and volume time series from 01/02/2001 to 10/30/2009 obtained in YahooFinance. The *manager* starts with zero stocks for each company in the sector and with one million in cash. This money is equally distributed between the companies of the sector and is exclusive for trades in each company stock.

4.2 Simulation Results and Analyzis

The table 1 shows the consolidate FAS portfolio and compare it with different sector and financial market benchmarks. The results of each *fundamentalist analyst* are compared among themselves for the eight years of simulation in order to validate the implementation and performance of the analysis. Furthermore, those analyses are compared with the *manager* performance in order to validate if the *manager* really benefits from the analyses composition.

Table 1. Accumulated return, risk and Sharpe ratio achieved by FAS and sector portfolios.

	2002	2003	2004	2005	2006	2007	2008	2009	Risk	Sharpe ratio
FAS	3%	17%	41%	48%	61%	76%	55%	63%	24,6%	3,0
Metals	-16%	19%	124%	130%	218%	346%	70%	89%	115,4%	0,9
Oil&Gas	-17%	12%	89%	131%	166%	182%	123%	128%	70,6%	2,0
Software	-20%	6%	14%	16%	28%	29%	8%	22%	15,6%	2,1
Automobile e Parts	-37%	-8%	-4%	-12%	25%	26%	-14%	-2%	20,5%	0,4
Comp. and Office Equip.	-29%	5%	66%	89%	126%	183%	88%	171%	74,1%	2,4
SP500	-22%	-2%	4%	12%	24%	20%	-24%	-11%	18,3%	0,0
Total Sector	-24%	7%	58%	71%	113%	153%	55%	82%	55,7%	1,7
Risk Free Asset	5%	10%	14%	19%	24%	30%	36%	41%	-	-

We also compare the *manager* performance with the performances of the stocks in the sector and benchmark market index such as S&P500 and the sector portfolio, compound of equal portion of the stocks in the sector, in order to validate the *manager* performance against the financial market. These performances are compared using a well known index from finance theory, the Sharpe ratio [12], where the return of the risk free asset is the return of a benchmark (in the work S&P500 was used as benchmark).

The achieved results show that FAS has the best (highest) Sharpe ratio when compared to sector portfolios, table 1. However, FAS is just the fifth in accumulated return from 2002 to 2009, nevertheless it got 63% in that period. As explained in section 4.2, Sharpe ratio is defined by the return above a benchmark return divided by the risk, measured as standard deviation of returns. Therefore, the best position in Sharpe ratio can be explained, due to the good performance in risk . FAS presents the second best (lowest) risk, see table 1.

5 Conclusions and Future Work

The AgEx tool presented in this paper is a special-purpose software agent platform for simulation of financial markets, with support to traders that rely on fundamentalist analyses. It is open source and allows market simulation with prices from real markets. It makes available a market ontology that simplifies communication. AgEx provides facilities to launch traders from several computers over the net and to analyze their performances.

We presented a multiagent trader system, FAS, developed with AgEx and based on fundamentalist analysis. FAS has shown to be a promising system for the automate asset portfolio administration using fundamentalist analysis. The system showed that can maximize the index Sharpe with an asset portfolio balanced between risk assets, stocks, and risk free assets, treasury bonds. Besides, it showed consistency in its long-term returns due to a lower exposure of market oscillations. Finally, we believe that AgEx new version can be very useful for others researchers trying to develop new trading strategies based on technical or fundamentalist analyses.

References

1. Michael Kearns and Luis Ortiz. The penn-lehman automated trading project. *IEEE Intelligent System*, 18(6):22–31, 11-12 2003.
2. Andrew D. Costa Bruno Borsato Fábio A. Soares Sérgio C. Azevedo, Manoel Teixeira and Carlos J. P. Lucena. Multi-agent system for stock exchange simulation - masses. In *Proceedings of the Fourth Workshop on Software Engineering for Agent-oriented Systems - SEAS*, Campinas, Brasil, 2008.
3. Paulo Andre Castro and Jaime Simao Sichman. Agex: A financial market simulation tool for software agents. In *Proceedings of 11th International Conference on Enterprise Information Systems. ICEIS.*, pages 704–715, Milan, Italy, 2009.
4. Graham Kendall and Yan Su. A multi-agent based simulated stock market - testing on different types of stocks, 2003.
5. Alexander Sherstov and Peter Stone. Three automated stock-trading agents: A comparative study. In *Proceedings of the Agent Mediated Electronic Commerce (AMEC) Workshop - AAMAS 2004*, New York, 2004.
6. Yi Feng Yuriy Nevmyvaka and Michael Kearns. Reinforcement learning for optimized trade execution. In *Proceedings of the 23rd International Conference on Machine Learning- ICML 2006*, Pittsburgh, Pennsylvania, 6 2006.
7. Xin Feng and Chang-Hyun Jo. Agent-based stock trading. In *proceedings of the ISCA CATA-2003*, Honolulu, Hawaii, 3 2003.
8. Graham Kendall and Yan Su. A particle swarm optimisation approach in the construction of optimal risky portfolios. In *proceedings of the 23rd IASTED International Multi-Conference Artificial Intelligence and Applications*, pages 140–145, Innsbruck, Austria, 2 2005.
9. FIPA. Fipa. the foundation for intelligent physical agents, 2009.
10. Aswath Damodaran. *Avaliação de investimento: ferramentas e técnicas para a determinação do valor de qualquer ativo*. Qualitymark Ed., Rio de Janeiro,Brazil, 1997.
11. Hime Aguiar e OLIVEIRA Jr. *Inteligência Computacional aplicada à administração, economia e engenharia*. Thomson, São Paulo, 2007.
12. William F. Sharpe. The sharpe ratio. *Journal of Portfolio Management*, 13(3):227–286, 1994.