# Financial and Managerial Benchmark Problems for Nature Inspired Intelligence

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**ABSTRACT**

The presence of benchmark problems provides an important stimulus in fields related to the development of new methodologies. Currently, benchmark data for nature-inspired networks are scarce. To increase the collection of benchmark data, we propose, in this work, a number of interesting and rather difficult managerial and financial decision problems that can be found in the literature. Usually, similar problems are addressed by methodologies belonging to statistics, operations research, mathematical programming, heuristic algorithm implementation, and classical artificial intelligence. We believe that nature inspired intelligence constitutes a challenging alternative for handling these problems effectively. For this reason, we collect formal problem descriptions, related data collections, presentation of existing solutions and comparison of the performance obtained by nature inspired approaches to other existing methodologies.

KEYWORDS: nature inspired intelligence, managerial and financial decision making, nature inspired networks, cross dynamics of international financial markets, orienteering problem, analysis of bubbles in asset prices, benchmark data.

## 1. INTRODUCTION

The presence of benchmark problems provides an important stimulus in fields related to the development of new methodologies. Benchmark problems help focus the research effort in a field on a finite number of well-known problem instances that can be tackled by different research groups. Hence, they generate a common basis for comparing new developments, as well as a partial common terminology that helps compare the merits of various approaches. Within the frame of the NISIS Network[1], work is being done to investigate the nature, modelling and control of nature-inspired networks [3]. This work will definitely benefit from the formulation of problem areas and instances that can be used as benchmark data. We propose, in this paper, the collection of such representative data, research reports and related supporting material, for a number of indicative problems from the fields of economics, finance and management. As the Nature-Inspired Networks Focus Group of NISIS Network has already expressed its interest for the application of nature inspired methods to finance and management, special emphasis is to be given to those problems which can be represented as networks. The idea is to use the collected material as benchmark financial and managerial problems, trying to apply different nature inspired intelligent methodologies and compare the acquired solutions to those arising from competitive approaches existing in literature.

For a long time, natural and biological processes increasingly influence science and technology methodologies. Among the most successful nature inspired methodologies are those related to cybernetics, such as classical feedback control, artificial neurons, advances in bioinformatics and genomics, natural immunological systems, evolutionary computation, etc. A recent advance in the above field is nature inspired intelligence, an extension of intelligent information systems

[1] NISIS: Nature Inspired Smart Information Systems, see www.nisis.de for more details.

which correspond to mechanisms able to learn and adapt on-line by either updating parameters or structures of the system in a stable and reliable manner [1].

The development of nature inspired methodologies is in fact an attempt to join forces between engineering and life sciences. The idea came from the need to understand naturally occurring phenomena, characteristics of self-emergent systems, as well as to achieve new robust and reliable methodologies for handling uncertainty and dynamic behaviour. Nature-inspired (Ni-) methodologies are based on the understanding of natural living systems either at the biological (micro) or at the behavioural (macro) level. Certain Ni-techniques perform data analysis and mining using innovative techniques taken from microbiology, others incorporate highly accurate measurement or monitoring techniques taken from physics and chemistry and a number of them mimic the behaviour of animal colonies or bird migration flocking for the purpose of a fast and effective multi-objective optimization.

Nature inspired networks are considered a subcategory of nature inspired smart information systems, which are of particular interest for researchers, for two reasons:

a) there exist various natural systems which appear to have a network formation and in real life achieve high level performance either at the micro or at the macro level, and

b) there are various real world problems of nowadays, whose main characteristics and complexity are similar to that of natural systems.

In the first category belong the multi-cellular biological structures, the development of multi-cellular organisms, the adaptivity of individuals to environmental changes through learning, the species adaptation, the cell differentiation and the cell reproducing, etc. The need for the construction of evolvable hardware and fault tolerant network design, the study of internal dynamics in complex systems, and the management of information networks where knowledge is distributed through multiple processing elements, are representative cases of the second category.

Business and economic systems can be viewed as networks of information processing entities that pursue their own goals and interact with one another in a multitude of flexible ways. Economic theory has developed a number of methods for modelling such networks and analysing the desirable properties of their operation. Theories regarding the workings of markets, microeconomic systems, influence of adverse information effects and the influence of transaction cost effects can be given as examples. These results could be used to allocate resources efficiently and effectively in complex information systems, to design frameworks in which such information systems can operate and to guide the emergent properties of complex information systems. Already artificial markets are being designed, investigated for optimisation in decentralised network systems (e.g. optimal scheduling in IT systems for supply chain management) and information sharing (artificial information markets for autonomous agents). Thus, input from business/economics is important for smart information systems, which motivates our search for benchmark problems from this field of knowledge.

The outline of the paper is as follows. In Section 2, we describe a few representative network problems from economics, finance and management, suitable to be handled by nature inspired smart information methodologies. In Section 3, we provide some details regarding the methods and procedures we intend to use to collect the data. Finally, conclusions are given in Section 4.

## 2. INDICATIVE NiN-BENCHMARK PROBLEMS

### 2.1 CROSS DYNAMICS OF INTERNATIONAL FINANCIAL MARKETS

International financial markets form an interesting network on which information is exchanged and continuously discounted. Each node of the network (i.e. financial market) is not an autonomous entity. Shocks to one market are not indifferent as to the future behaviour of the other markets. For example, the recent history of an influential American stock index, e.g. the NASDAQ or S&P 500, may be relevant to predicting the course of an Asian index though the opposite may not hold. This is because markets are not equally influential and informative; there are leading and "following" nodes. Inter-dependencies between nodes of the network are also time variant and depend on the historical period under study. In certain instances, groups of international indexes, such as the U.S., German and French, may be found to follow each other, meaning that they tend to satisfy a long-run equilibrium relationship. Under other circumstances, those indexes may meander without any tendency to come together. Of course, equilibrium relationships are by no means static, as neoclassical economic theory dictates, and they certainly do not last forever. Unexpected changes taking place either in the global environment (oil crises, wars, monetary unions etc.), or in the domestic economy can often decouple markets and cause short-run deviations from the equilibrium relationship which can be rather persistent. Under other circumstances, such shocks can have a permanent effect on the long-run behavior of the network, moving a group of markets to a new unforeseen equilibrium. Just as natural systems adapt to environmental changes (e.g. temperature changes, harsh weather conditions, etc), markets respond to unpredictable incoming economic and political information. However, economic fundamentals do not represent the only driving factor of prices.

The expectations and predispositions of market agents act significant pressure on market prices and are often a more important determinant of market moves than fundamental news. Such expectations are not solely based on economic fundamentals but also on irrational exaggeration. Although certain policies and economic decision are intended to favor certain market reactions, the "mood" of market agents can drive prices in opposite direction. The types of inter-temporal dependencies between international markets can be summarized in three hypotheses,

(a) short-term mean dependencies,
(b) long-run relation, and
(c) volatility spillovers.

This type of interdependency amongst markets can be modelled in a network structure, and analysis of such systems can push forward the understanding of nature-inspired smart information systems.

## 2.2 INFORMATION DIFFUSION IN ARTIFICIAL STOCK MARKETS

A typical case of a financial engineering problem represented as a network can be considered that of artificial stock markets. An artificial stock market consists of buyers and sellers, which are coordinated by market makers (agents), thus forming a market network. The sellers make bid offers by adopting specific strategies, while the buyers ask for offers. The aim is to observe the whole situation through the related data generated within the market, to try to identify the price formation mechanism, to control how prices are determined and to find possible regularities that may appear. The above market network problem can also be generalized to represent intra-relationships within any social network, including behavioural aspects of human communication, thus becoming an interesting tool for analysing also complex managerial situations related to human factors, human resources management, and the diffusion of information.

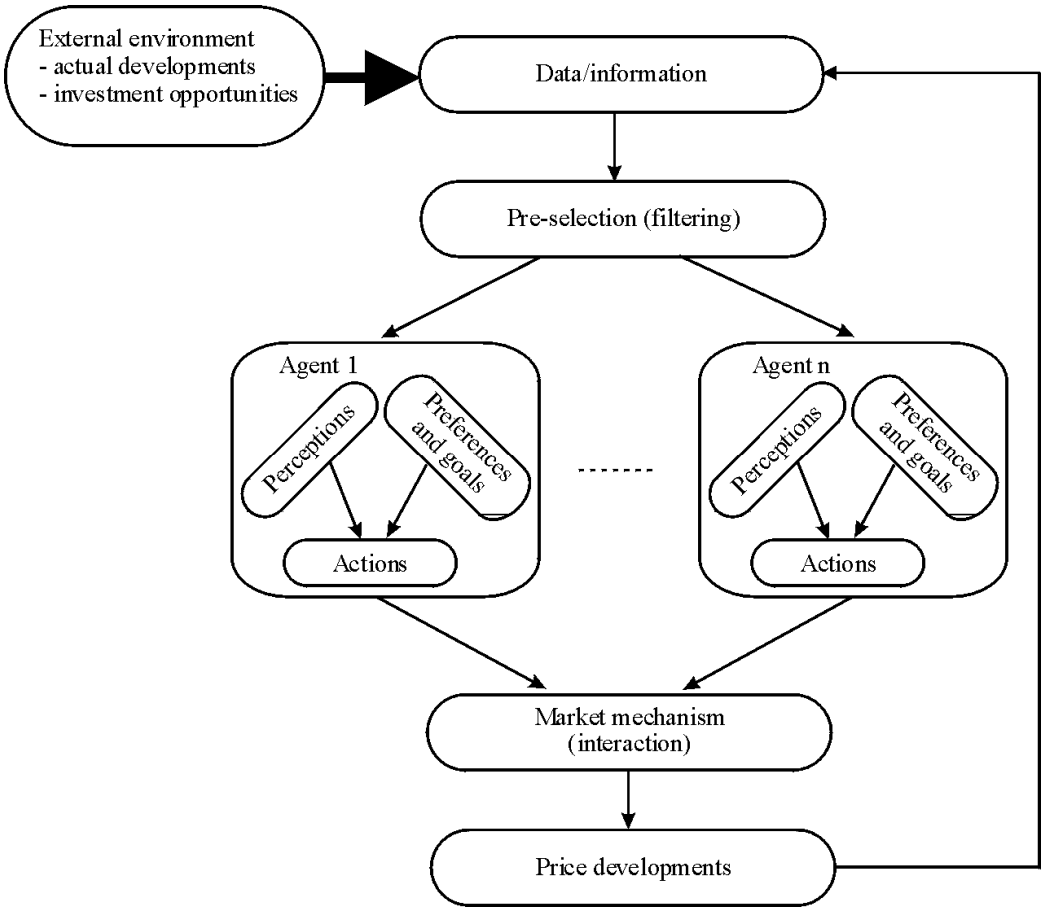


**Figure 1 Information diffusion in financial markets.**

A general framework for information diffusion in financial markets has been discussed in [2], and is shown in Figure1. Price formation in financial markets is a result of the interaction between the market mechanism, the trading decisions of multiple parties and the external developments influencing the markets. The trading decisions of the traders depend on the available information. The resulting trade actions determine the price developments. The price developments

enter the decision-making system again as new data. Actual developments in firms, markets, (macro) economic conditions and other investment opportunities provide new information that enters a pool of available information and data in the market. Usually, only part of all the information is available, or it may be available to only a group of economic agents that select it in different ways. This is effectively a filtering step. The traders in the markets (i.e. different agents) perceive and interpret the filtered information in different ways. Depending on their individual goals, preferences and their interpretation of the available information, the agents take different trading actions, which lead to the price developments through the interaction at the market. The market mechanism and its internal structure determine the nature of this interaction. The price developments are in turn available as further information in the market, upon which the traders may modify their trading decisions. The participants in the financial markets have different attitudes to risk, different time horizons and different motivations leading to different reactions to unexpected (or even expected) news. Nature-inspired methodologies can be used to model these differences, as well as the learning and the adaptation behaviour of the traders. It becomes then possible to study explicitly the influence of dynamics at a microscopic level, and to study how these dynamics eventually lead to the macroscopic behaviour observed at the markets. In general, one needs to study the information diffusion at the markets and the expectation formation by the agents. Using such a framework, one can observe the system in controlled experiments, where only one of the factors is modified, and hence one can assess the validity of various hypotheses. Of particular interest are the social structures, networks and interactions that exist amongst the traders, which should help demonstrate interesting aspects of nature-inspired networks.

### 2.3 THE ORIENTEERING PROBLEM

Production and operations management offers a variety of optimization problems, suitable to be handled by nature inspired smart information approaches. A number of these problems can be represented in the form of a network, the so-called orienteering problem being a representative one. Given a set of control points with associated scores along with the start and end points, the orienteering problem deals with finding a path between the start and end points in order to maximize the total score subject to a given distance budget. Due to the fact that distance is limited, tours may not include all points. It should be noted that the orienteering problem is in fact equivalent to the travelling salesman problem when the time is relaxed just enough to cover all points and the start and end points are not specified.

### 2.4 ANALYSIS OF BUBBLES IN ASSET PRICES

Bubbles are a typical example of herding behavior in financial markets. When investors follow each other's judgments by not taking into account fundamental information, asset prices are pushed at levels that are far from fundamentals. Many econometric models and tests have been proposed in the literature for the detection and early prediction of bubbles. Nevertheless, despite recent advances, detection of bubbles still cannot be achieved with a satisfactory degree. Apart from problems caused by small samples, most methodologies are also unable to distinguish bubbles from time-varying or regime-switching fundamentals. For the investigation of bubbles in asset prices, mainly two research directions are followed in the literature, the *micro* and the *macro* one. The micro approach focuses on the creation of artificial analogs of the real underlying market, by assuming certain types of market agents (e.g. experienced and inexperienced ones) and a specific market structure (i.e. an order placing platform, market-making, etc.). Micro approaches investigate the formation of bubbles by observing periodic shifts in artificial agents' attitude and the emerging of herding. The so-called macro approach follows an inverse direction by focusing on the outcome of the interaction of real market agents. In this approach, early detection of bubbles is attempted by observing other signals that come with the formation of bubbles. Those are for example changes in the conditional skewness, volatility and an increase in trading volume. Nature-inspired methodologies can be used in both levels of analysis, as micro and macro models of the asset market.

## 3. APPROACHES TO DATA COLLECTION

The four problems that we have described above have different characteristics. Depending on these different characteristics, data collection will take different forms. Cross-dynamics of international markets can be considered as a data mining related problem, where the characteristics of the network structure amongst the financial markets need to be modelled. For this, we will collect data for different markets from different sources. Daily data for this purpose are readily available. However, additional processing will be needed to synchronize events at different markets, such that a consistent picture of the activities and developments at different markets can be obtained. If this is successful, one could focus on obtaining high frequency data at the hourly or minute level. However, such data are less readily available and usually there are additional costs for buying these data.

Information diffusion in artificial stock markets allows controlled experimentation in a simulated network structure. The main challenge here will be to design the specific behaviours of the agents whose interaction lead to the complex patterns observed. We will do a brief investigation into the beliefs, desires and intentions of the traders and model the most promising behaviours, generating data for a number of cases. A simulation environment for this purpose is available from the Erasmus University Rotterdam, in the Netherlands [4].

The orienteering problem concerns optimization in network structures. There are multiple standard problem instances for this type of problem, such as the travelling salesman problem as a special case. Most of our work for this part then consists of reviewing the literature for the most typical problem instances and identifying the interesting problems for the nature-inspired approaches.

Analysis of bubbles in asset prices is related both to data mining problems and the network analysis problems. For the micro approach, simulation is again a powerful tool to generate relevant data under controlled and well-defined conditions. For the macro approach, data are available through various national and international institutes, the Internet and brokers who specialize in supplying economic data. We expect most of the effort to focus on free available data, to be augmented with other indicators as the need arises.

## 4. CONCLUSIONS

As mentioned above, the scope of defining benchmark Ni- or NiN- problems is to collect corresponding data for future experimentation with various nature inspired methods. Related competitive methodologies (papers, code, etc.) for handling the selected benchmark problems will also be collected for comparing the results obtained from nature-inspired approaches. Comparison will take place either in terms of accuracy and processing speed, or in terms of comprehensibility, capture of dynamic behaviour, adaptation skills, handling of noise, effective modelling and estimation capability. The construction of a related website containing benchmark data and related methodologies / results for these data, is likely to attract researchers and practitioners working on similar problems and applications, from the areas of finance, economic decision making, business, trade, finance, operations research, industrial engineering, etc. The attempt could become a reference point for the presentation and experimentation with selected benchmark financial and managerial problems being in a form compatible to that of nature inspired intelligent systems and particularly of nature inspired networks.

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